MOTION ESTIMATION IN BRAIN TOPOGRAHIC MAPS

By

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Submitted to the Electrical & Electronics Engineering Programme

in Partial Fulfilment of the Requirement

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CERTIFICATION OF APPROVAL

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Project Supervisor

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgments and the work contain herein have not been undertaken or done by unspecified sources or person.

Gowri Gopalakrishnan

ACKNOWLEDGEMENT

First and foremost, my utmost gratitude to God for giving me the strength and guidance to complete this research project successfully.

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To my beloved family members, you have always been inspiration to me. Thank you for endless love and support.

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ABSTRACT

The objective of brain mapping is to advance knowledge in understanding the brain functions with its respective structures. Current technologies and advances in brain imaging technique using EEG *(electroencephalogram)* allows estimation of network connection which represents activity that occur in different structures of human brain. As the EEG procedure is simple and harmless, it is widely used to study the brain behavior and cognitive processes such as memory, language, emotions, sensation and alertness. In past study, ten healthy subjects (five female and five male) undergo an experiment consists of 200 trials. These trials include two stimulus consist of X and O which appears randomly. Subjects required to respond to X and ignore O. Signals gained from these events evaluated as topographical properties of brain network. Note that, only segment of interest will be plotted on topographic maps. In present research, these topographic maps will be used to study the behavior of the brain signals due to presence of stimulus. Motion estimation is an interesting analysis of tracking movement of signals around brain region. Currently, no proper motion estimation technology is available for this purpose. Development of motion estimation system allows us to observe and study movements of brain signals. In this project, I've applied Full Search Algorithm on brain topographic. Movement of signals detected based on general matching criteria which will be further discussed in the literature review.

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

EEG is defined as an alternating positive and negative electrical signal due to response or reaction between neurons on the scalp surface. These signals picked up by conductive media such as metal electrodes [1]. In most studies, EEG is used to record Evoked or Event Related Potential (ERPs) [2].ERP are irregular relative voltage resulting from alternating positive and negative neural activity. Note that, these neural activities initiated by an external or internal stimulus [3].

In present study, these neural activities evaluated as sequence brain topographic maps over time. The alternating positive and negative signal color mapped in grayscale where white represent most positive signals while black represent most negative signals. Motion estimation is an interesting analysis of tracking movement of signals around brain region. Currently, no proper motion estimation technology is available for this purpose. Development of motion estimation system allows us to observe and study movements of brain signals.

1.2 Objective

- Apply Motion Estimation algorithm on brain topographic maps to track movement of signals around brain region.
- Study how activation moves around brain region over time.

1.3 Scope of Study

Research/Study

Literature review on available motion estimation methods and works done so far in that area. Among the methods studied are: Full search, three step search, four step search, optical flow etc.

Besides that, studies carried out related to brain anatomy especially on the structure and functions of Cerebrum Cortex which is the largest part of the brain. The Cerebrum Cortex responsible for voluntary behaviors such as muscle movement, sensation, thinking, reasoning, and memory.

Design

Design a system, which estimates motion in brain topographic videos using MATLAB. From the literature review, it is justified that Full Search Algorithm is an efficient and simple method to estimate motion in video frames. Generally, Full Search Algorithm finds the location with minimum Block Distortion Measure or BDM *(Kindly review section 2.1)* of all displacements within a given search range.

Testing and Error Correction

Debug the system to produce reliable results. The process includes examine the errors and troubleshoot. Unlike video compression, brain topographic maps contain intensity which changes smoothly from one frame to another and not so apparent.

Analysis

Analyze the results. Observe the movements which occur in the brain map and relate them to the study. In our research, we will relate this behavior to the stimulus present.

Application

Use the system to estimate motion in brain topographic maps.

2.4 Timeline

The project is feasible within the scope and time frame. Given the time frame below:

Month	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Paper Review								
Testing & Modification								
Implementation & Error Correction								
Analysis & Application								

figure 1: General Time Frame for the project

CHAPTER 2

LITERATURE REVIEW

2.1 Full Search Algorithm

Full Search Algorithm (FS) is the most computationally expensive block matching algorithm of all. Consider the sequence of images below;

figure 2: Sequence of images in a video

Let's call the current image frame as the *Target Frame*. The previous or future frame is called as the *Reference Frame*.

(a) (b) (c)

figure 3: (b) is the current frame while (a) or (c) can be the reference frame

Each images divided into macro blocks with size N X N. The match is the resemblance between the macro block in the *Target Frame* with the macro block in *Reference Frame*. The movement of the macro block to a new location called as *Motion Vector (MV)* [4]. MV limited to specified macro block neighborhood which ranges $[\rho, -\rho]$.Therefore, the search window size is defined to be $(2\rho + 1) \times (2\rho + 1)$ [5].

Figure 4 illustrates the example of forward prediction in which the pervious frame taken to be the reference frame.

Reference Frame **Target Frame**

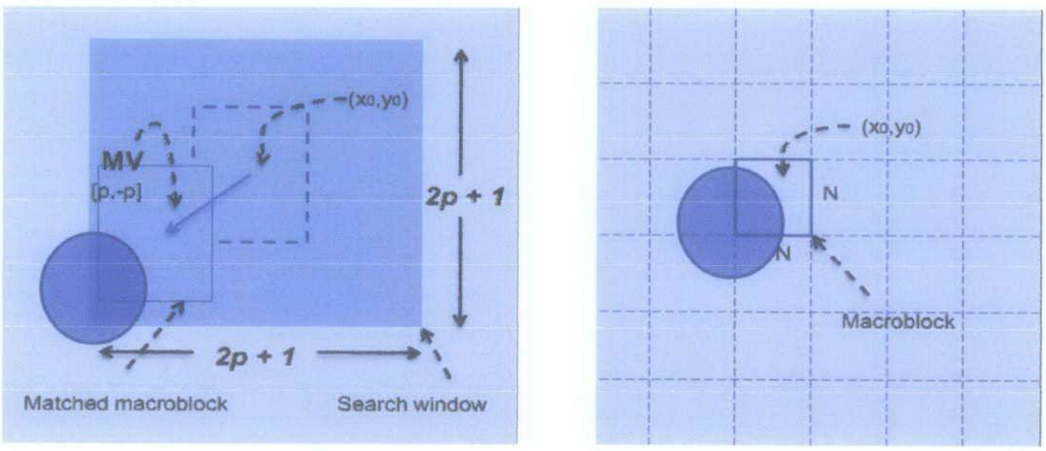


figure 4 : Forward Prediction, taking pervious frame as reference

The matching of one macro block with another is based on the output of the matching criteria. Macro block matching most criteria is considered as the one that matches current block. To do this, we apply Block Distortion Measure (BDM) which includes few matching criteria. The most popular and simple matching criteria is Mean Absolute Difference (MAD), given by equation:

$$MAD = \frac{1}{N^2}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}\left|C_{i,j} - R_{i,j}\right| \qquad (1)$$

Other matching criteria include Mean Square Error (MSE). MSE is the cumulative squared error between the target and reference macro block, given by equation:

$$MSE = \frac{1}{N^2}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}\left(C_{i,j} - R_{i,j}\right)^2 \qquad (2)$$

For equation (1) and (2), N is the size of the macro block, Ci,j and Ri,j are the target and reference macro block, respectively. Besides that, PSNR is another matching criteria which measures the peak error. The equation for PSNR is given by;

(3)

$$PSNR = 10log_{10}\frac{peak\ to\ peak\ of\ original\ data^2}{MSE}$$

For equation (3), peak to peak of original data represent the maximum value of pixels in the original image. In most cases, this value will be 255 *(for 8 bits image).*

There is another popular BDM taken into consideration, which is the Maximum Matching Pixel Count [6], given by equation:

$$U(x,y),V(x,y) = argmax \sum_{i=0}^{N-1}\sum_{j=0}^{N-1} T(x+i,y+j;u,v) \qquad (4)$$

Where U and V is the current and reference macro block, N is the size of the macro block and T is the Maximum Matching Pixel ınt. The more matching pixels found, the higher matching criteria achieved. When similar macro blocks detected to have similar BDM, the closest macro block to the initial location selected. Here, we apply the concept of Euclidean Distance. Figure 5 shows the basic concept of Euclidean Algorithm. Since Full Search method will be looking at neighborhood distance, the concept above modified to fit our requirement.

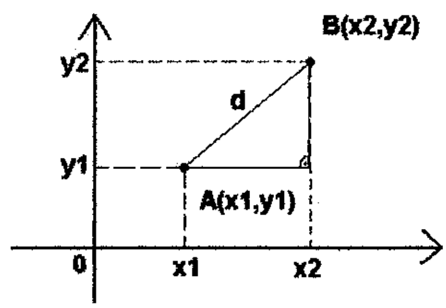


figure 5: Distance between point A and B

The distance between point *(x1,y1)* and *(x2,y2)* given by equation;

$$d = \sqrt{(x2-x1)^2 + (y2-y1)^2} \qquad (5)$$

Figure 6 shows how Quasi Euclidean marks distance from the centre.

0	0	0	0	0
0	0	0	0	0
0	0	1	0	0
0	0	0	0	0
0	0	0	0	0

(a)

2.8	2.4	2.0	2.4	2.8
2.4	1.4	1.0	1.4	2.4
2.0	1.0	0	1.0	2.0
2.4	1.4	1.0	1.4	2.4
2.8	2.4	2.0	2.4	2.8

(b)

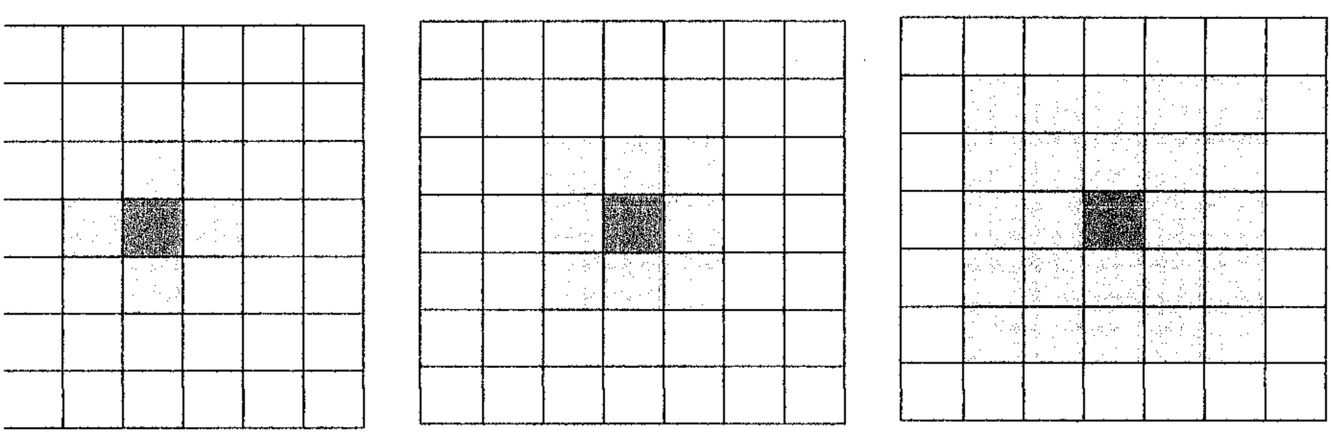
figure 6 : (a) Initial location marked as 1 (b) Quasi Euclidean mapping gives priority to the closest macro block with the initial location

There are three orders of quasi Euclidean distance [7];

(a) First Order: Locations selected from four possible selections in the d_4 neighborhood where the shortest chain-coded path defined. The distance map is equivalent to a d_4 map.

(b) Second Order: Locations selected from the eight possible selections in the d_8 neighborhood. Since each selection contributes with its true Euclidean distance, the resulting location is not equivalent to a d_8 map.

(c) Select the locations from a [5 5] neighborhood which gives 24 possible locations.



(a) (b) (c)

figure 7: Quasi Euclidean Distance mapping, (a) First Order, (b) Second Order, (c) Third Order

Figure 7 shows the difference between orders of Quasi Euclidean Distance Mapping

2.2 Optical Flow Estimation

Optical flow is a motion field where the physical movement of points relative to two dimensional displacement of pixel occur on an image plane [8]. Figure 8 shows how optical flow vector travels in a video sequence.

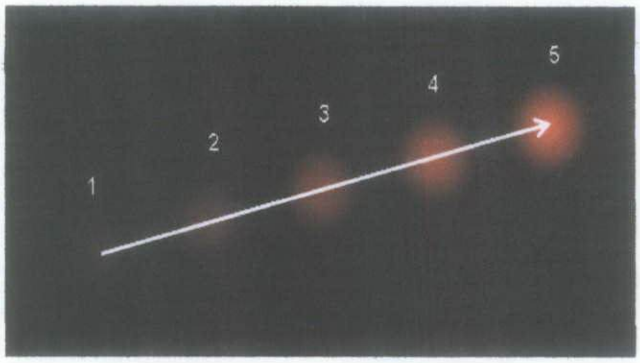


figure 8: Optical flow vector in a moving object in a video sequence

The brightness of image is assumed to be constant from frame to frame, then the motion associated to each pixel of *(x,y)* of image *I* can be modeled as;

$$I(x, y, t) = I(x + u\delta x, y + u\delta y, t + u\delta t) \qquad (6)$$

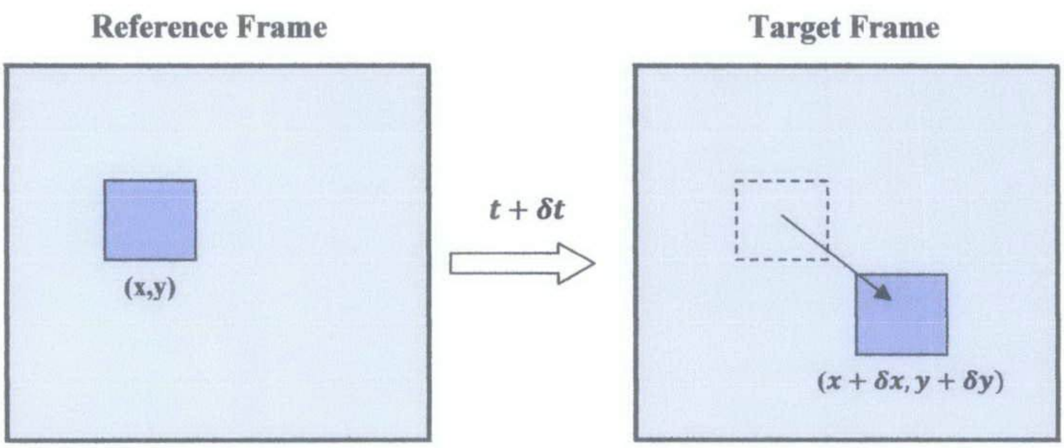


figure 9: image from position (x, y) at time t has moved to $(x + \delta x, y + \delta y, t + \delta t)$

Figure 9 illustrates the movement occur at δt.Assuming the movement is small, the image constraint at *I (x,y,z)* with Taylor series can be developed. The first order Taylor expansion is;

$$I_x U + I_y V + I_t = 0 \qquad (7)$$

$$E_{D=} \iint_R (I_x U + I_y V + I_t)^2 dxdy \qquad (8)$$

Recall equation (6), expend to;

$$I(x,y,t) = I(x,y,t) + \delta x \frac{dI}{dx} + \delta y \frac{dI}{dy} + \delta t \frac{dI}{dt} \qquad (9)$$

$$= \frac{dI}{dx} V_x + \frac{dI}{dy} V_{y+} \frac{dI}{dt} = 0 \qquad (10)$$

From the equation above, noted that the location *(x,y)* with intensity *I (x,y)* at time *t*, has a displacement of δ*x* and δ*y* at time *δt*. We can see that, V_x, V_y are the x and y component of the optical flow of intensity $I(x,y,t)$, while $\frac{dI}{dx}, \frac{dI}{dy}$ and $\frac{dI}{dt}$ are intensity derivatives of the image at *(x,y,t)* corresponding to I_x, I_y and I_t directions. Figure 10 shows application of Optical Flow.

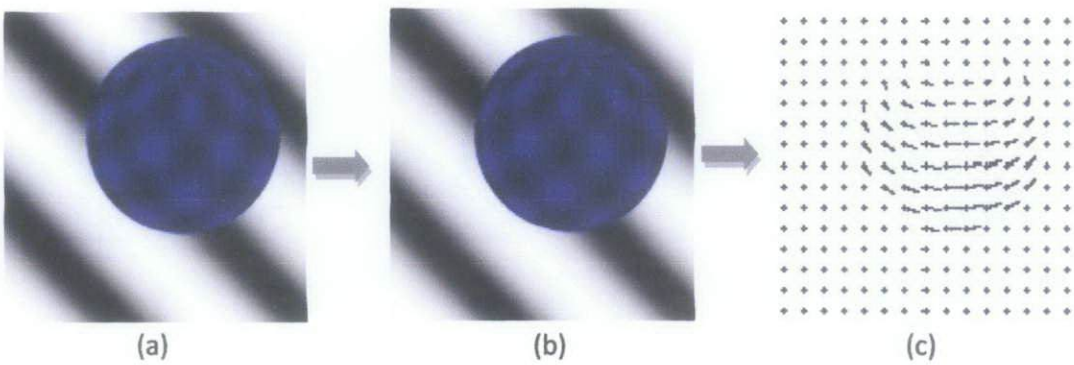


figure 10: Example of Optical Flow Estimation from (a) to (b)

The statement above can be rewritten as;

$$(I_x, I_y).(V_x, V_y) = -I_t \qquad (11)$$

$$\Delta I. \vec{V} = -I_t \qquad (12)$$

Where $\nabla I = (I_x, I_y)$ is the 2D spatial intensity gradient while $\vec{V} = (V_x, V_y)$ is the image velocity or optical flow at *(x, y)* at time *t*. Equation (12) is the *2D Motion Constraint Equation* which is an equation of a line with two unknowns [9].

Unfortunately, aperture problem occurs when there is lack of local image intensity structure to measure full image velocity, but enough structure to measure the normal component with the local intensity structure. Figure 11 illustrates the aperture problem.

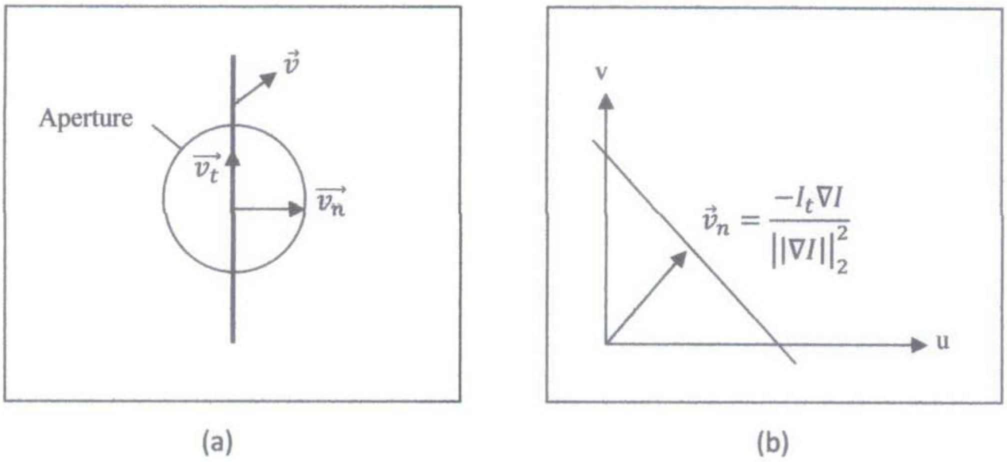


figure 11: (a) Able to restore normal velocity $\overrightarrow{v_n}$ but tangential velocity $\overrightarrow{v_t}$ cannot. (b) The motion constraint results a line of $\vec{v} = (v_x.v_y)^T$ space. Note that only one is the correct. The velocity with the smallest magnitude on that line is $\overrightarrow{v_n}$.

The displacement vector of the normal velocity, $v_n = v_n\hat{n}$ represented in terms of the intensity derivatives $I_{x,}I_y$ and I_t as:

$$v_n = \frac{-I_t}{||\nabla I||_2} \text{ and } \hat{n} = \frac{(I_x, I_y)}{||\nabla I||_2} \quad (13)$$

v_n and $\hat{n}$ normal velocity magnitude and the unit direction, given by equation;

$$\overrightarrow{v_n} = v_n\hat{n} = \frac{-I_t(I_x, I_y)}{||\nabla I||_2^2} \quad (14)$$

Besides that, the 2D motion constraint equation can be written as equation (12) which is;

$$\Delta I . \vec{V} = -I_t$$

Therefore, unit direction of normal velocity is $\hat{n} = \frac{(I_x, I_y)}{||(I_x, I_y)||_2}$ while the magnitude of normal velocity is $v_n = \frac{-I_t}{||(I_x, I_y)||_2}$ with respect to equation (13).

2.3 Other Block Matching Algorithms

2.3.1 Three Step Search

The Three Step Search (TSS) is one of the fast block matching algorithms which gets good reviews from researchers in the field of video compression. Different from Full Search (FS), TSS only searches at eight macro blocks per iteration *(total of three iterations)* to find the current macro block which matches the best with the reference macro block [10]. This means TSS searches total of 24 macro blocks. Compared to FS, TSS is faster but less efficient. This is due to FS searches all macro block within a user specified neighborhood. Figure 12 shows the search window which is constraint by p.

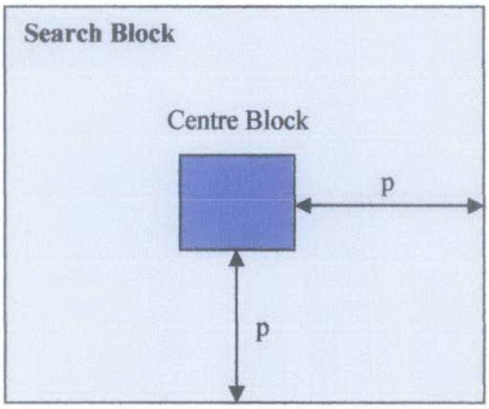


figure 12: Search window for Full Search Algorithm specified by window size p

Which gives total search of $(2p+1)^2$. Given the possible smallest value for search window is 4. FS searches for 81 locations before selecting the macro block with the best matching criteria. Table 2 shows steps involved in TSS.

Step	Description
One	Eight blocks at a distance of a step size from the centre of the block picked for comparison
Two	The step size is chose to be half. Centre moved to point minimum distortion and again eight blocks picked for next comparison
Three	Step one and two are repeated till the step size become one

table 1 : Steps involved in Three Step Search

In most cases, for TSS, we just need three steps of the whole algorithm to reach its final solution. Figure 13 illustrates how the blocks selected for TSS.

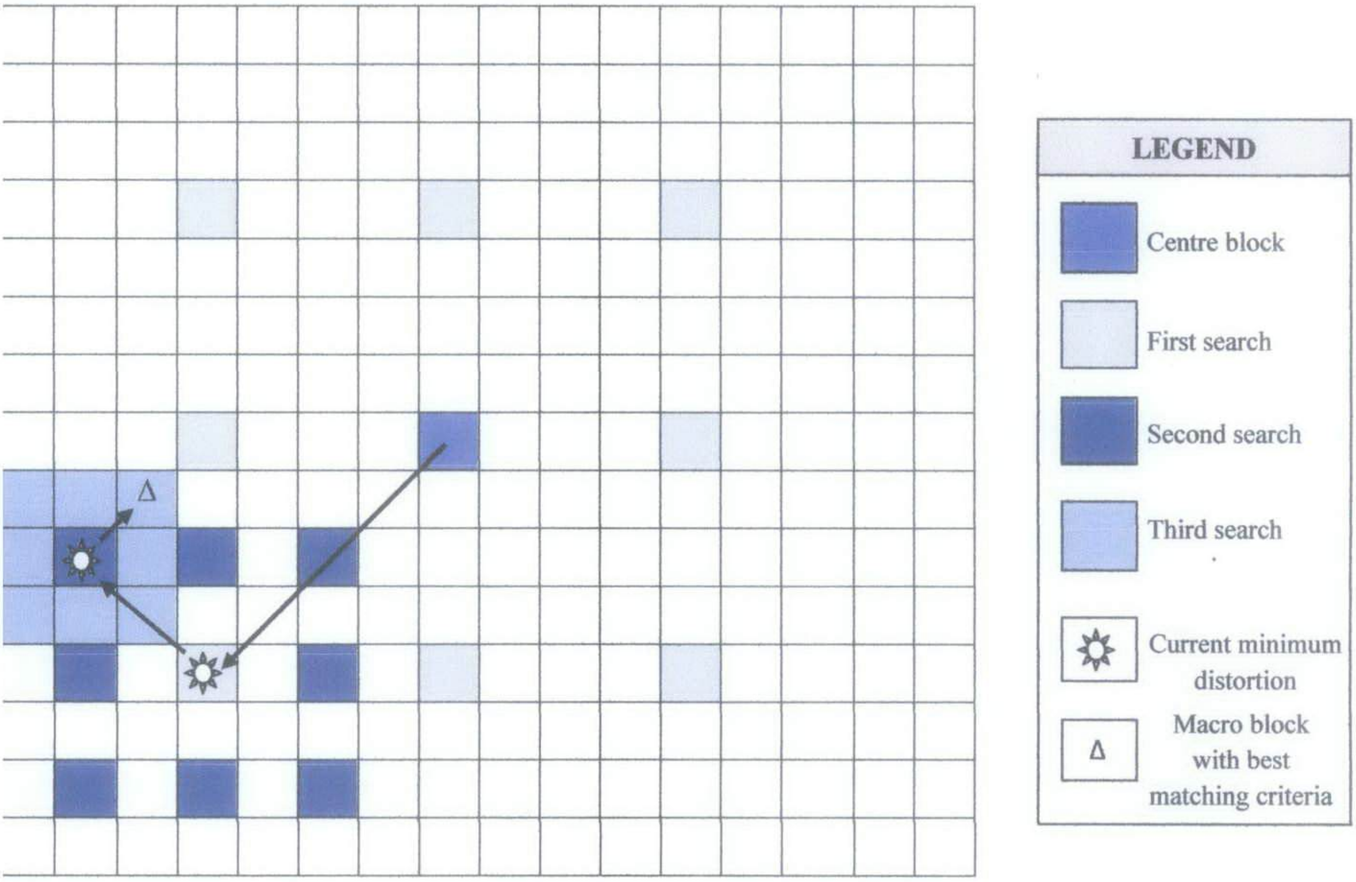


figure 13 : Example of Three-step with reduction of step size

2.3.2 Diamond Search

Diamond Search Algorithm (DS), searches in a pattern of diamond and there is no constraint on the number of steps taken to reach solution [11]. DS uses two different types of models;

(a) Large Diamond Search Pattern (LDSP)
(b) Small Diamond Search Pattern (SDSP)

As the search pattern is neither too small nor too big and the fact that there is no constraint to the number of steps taken to reach solution, this algorithm can find global minimum very accurately.

Table 3 shows steps involved in DS.

Step	Description
One	Use LDSP and if the least weight is at the center location we jump to the fourth search
Two	Check for matching criteria at point 3 or 5.
Three or Final	Use SDSP around the new search origin and the location with the least weight is the best match

table 2: Steps involve in Diamond Search

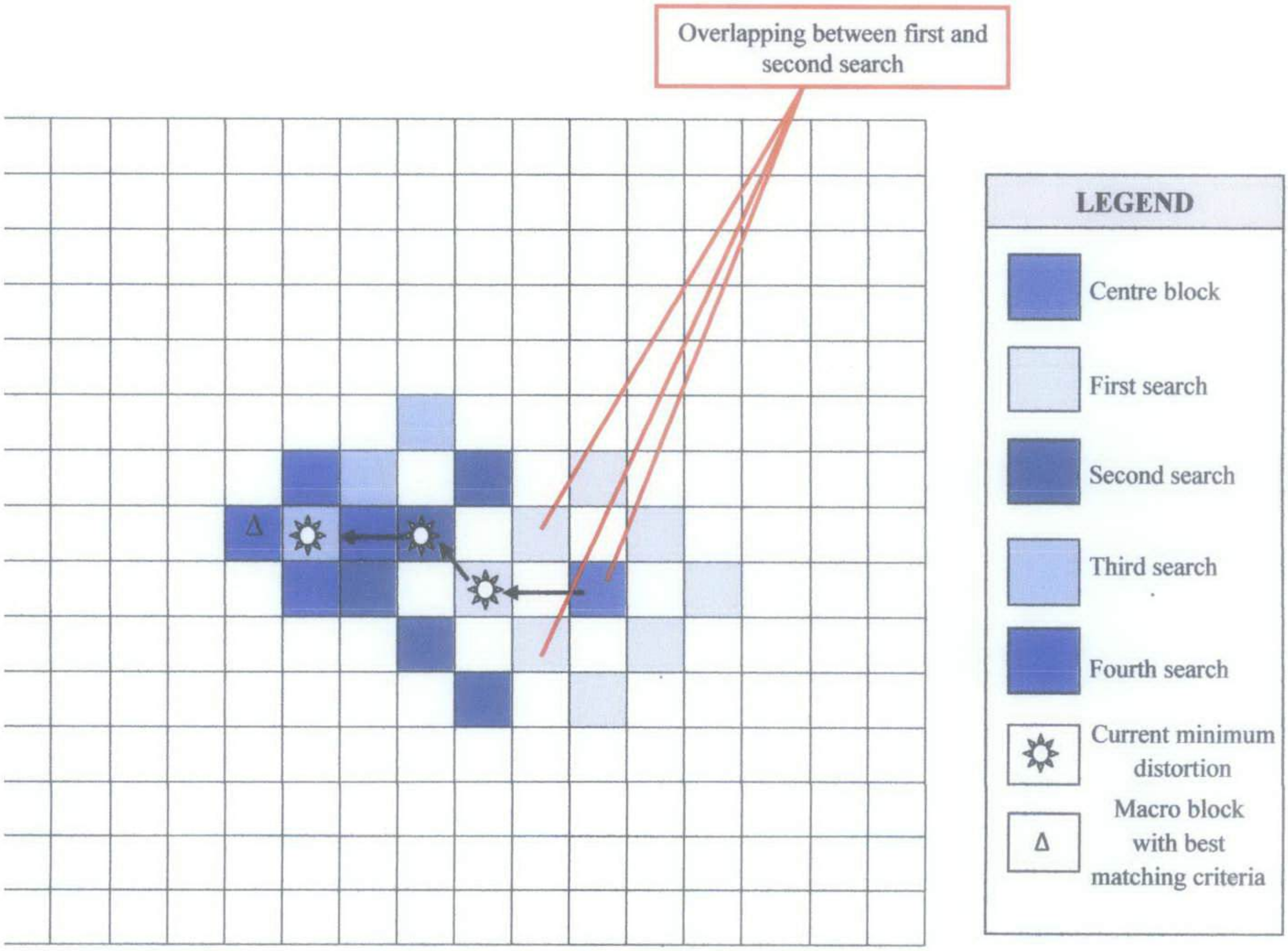


figure 14: Example of Diamond Search

Figure 14 illustrates how the blocks selected for DS. Note that search one till search three uses LDSP while search four uses SDSP.

2.4 General Brain Anatomy

The nervous system is known as decision making and communication center. The central nervous system (CNS) is made of the brain and the spinal cord and the peripheral nervous system (PNS) which is made of nerves [12]. Together they control every part of our daily life, from breathing to thinking.

2.4.1 Central Nervous System (CNS)

Sensory nerves gather information from the environment and send that info to the spinal cord, which then speed the message to the brain. The brain then makes sense of that message and fires off a response. Motor neurons deliver the instructions from the brain to the rest of your body.

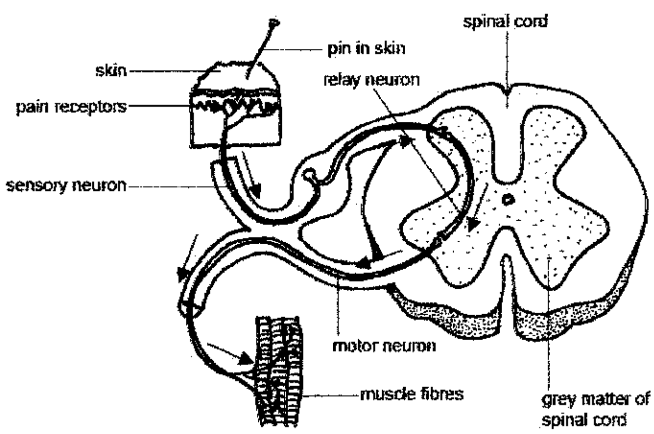


figure 15: Relationship between sensory nerves and spinal cord

2.4.2 Brain Divisions

The brain is made of three main parts [13]:

(a) Forebrain

(b) Midbrain

(c) Hindbrain

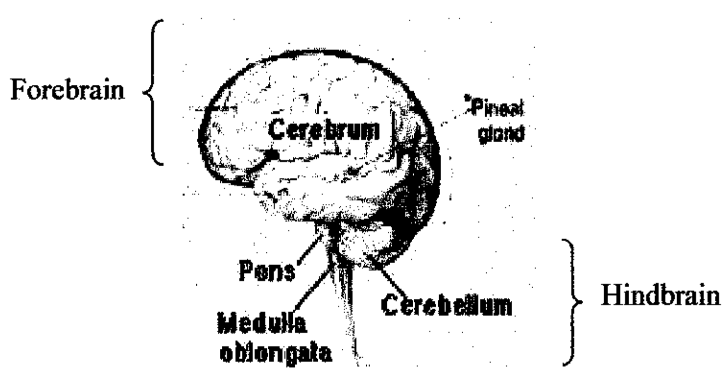


figure 16: Anatomy of the Brain

The functions of these main parts of the brain are described in the table below;

<table>
<tr><th>Brain region</th><th>Description</th></tr>
<tr><td>Forebrain</td><td>
Responsible for a variety of functions including receiving and processing sensory information, thinking, perceiving, producing and understanding language, and controlling motor function.

There are two major divisions of forebrain:
(a) The Diencephalon
(b) the Telencephalon

The diencephalon contains structures such as the thalamus and hypothalamus which are responsible for such functions as motor control, relaying sensory information, and controlling autonomic functions.

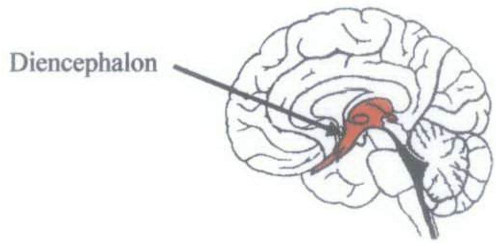


figure 17: The location of Diencephalon in the forebrain

The Telencephalon contains the largest part of the brain, which is the cerebrum. Most of the actual information processing in the brain takes place in the cerebral cortex.

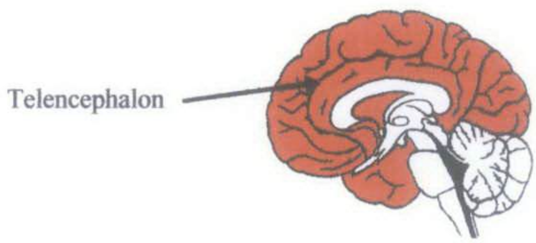


figure 18: The location of Telencephalon in the forebrain
</td></tr>
<tr><td>Midbrain</td><td>The midbrain and the hindbrain together make up the brainstem. The midbrain is the portion of the brainstem that connects the hindbrain and the forebrain. This region of the brain involved in auditory and visual responses as well as motor function.</td></tr>
</table>

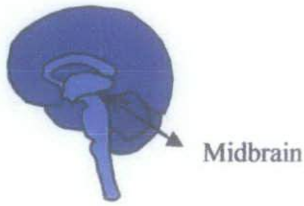
	 *figure 19: The midbrain which makes up a brain stem*
Hindbrain	The hindbrain extends from the spinal cord and is composed of; (a) Metencephalon (b) Myelencephalon The Metencephalon contains structures such as the pons and cerebellum *(Refer to figure 17)*. These regions assist in maintaining balance and equilibrium, movement coordination, and the conduction of sensory information. The Myelencephalon is composed of the medulla oblongata *(Refer to figure 17)* which is responsible for controlling autonomic functions as breathing, heart rate, and digestion.

Table 3 :The functions of Forebrain, Midbrain and Hindbrain

2.4.3 The Cerebrum

The cerebrum, also known as the *Telencephalon*, [14] is the largest and most highly developed part of the human brain. It encompasses about two-thirds of the brain mass and lies over and around most of the structures of the brain. The outer portion (1.5mm to 5mm) of the cerebrum is covered by a thin layer of gray tissue called the cerebral cortex.

The cerebrum is divided into right and left hemispheres that are connected by the *corpus callosum*.

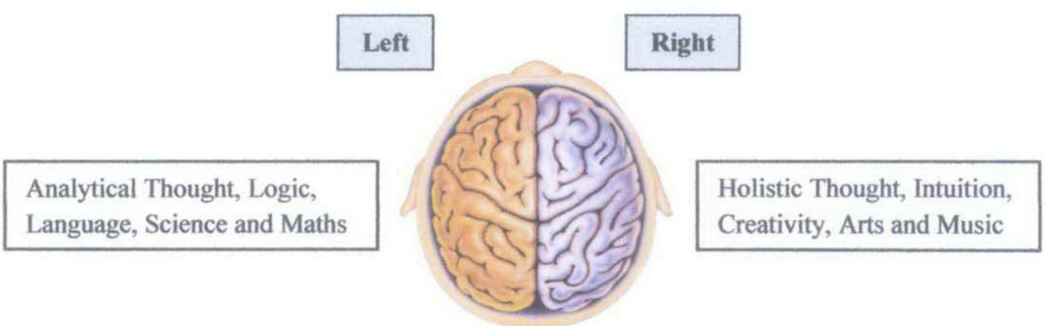


figure 20: Right and Left hemispheres with their functions

Each hemisphere is in turn divided into four lobes. The cerebrum, along with the *diencephalon* comprise the two major divisions of forebrain.

The cerebrum is involved in several functions of the body including:

- Determining Intelligence
- Determining Personality
- Thinking
- Perceiving
- Producing and Understanding Language
- Interpretation of Sensory Impulses
- Motor Function
- Planning and Organization
- Touch Sensation

The cerebral cortex is highly wrinkled. Essentially this makes the brain more efficient, because it can increase the surface area of the brain and the amount of neurons within it. The cerebrum is divided into four sections, called "lobes":

a) Frontal lobe
b) Parietal lobe
c) Occipital lob
d) Temporal lobe

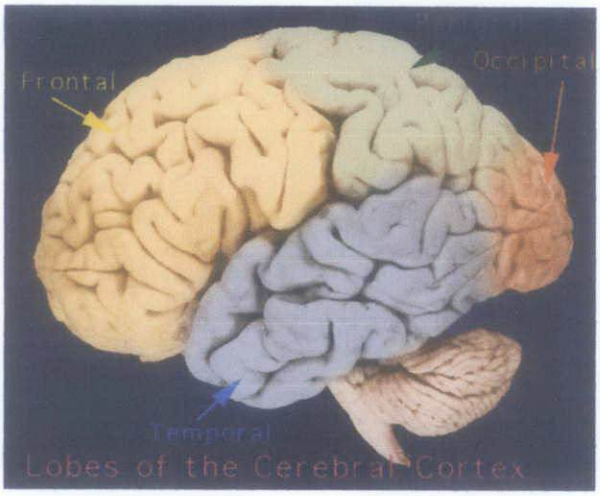


figure 21: Visual representation of the cortex

REGION	DESCRIPTION
Frontal Lobe	Associated with reasoning, planning, parts of speech, movement, emotions, and problem solving
Parietal Lobe	Associated with movement, orientation, recognition, perception of stimuli
Occipital Lobe	Associated with visual processing
Temporal Lobe	Associated with perception and recognition of auditory stimuli, memory, and speech

table 4: Brief description of Cerebral Cortex

2.4.3.1 The Motor Cortex

All body's voluntary movements are controlled by motor cortex [15]. The motor cortex is located in the rear portion of frontal lobe. The motor cortex divided into two main areas;

(a) Primary Motor Cortex
(b) Cortical Area

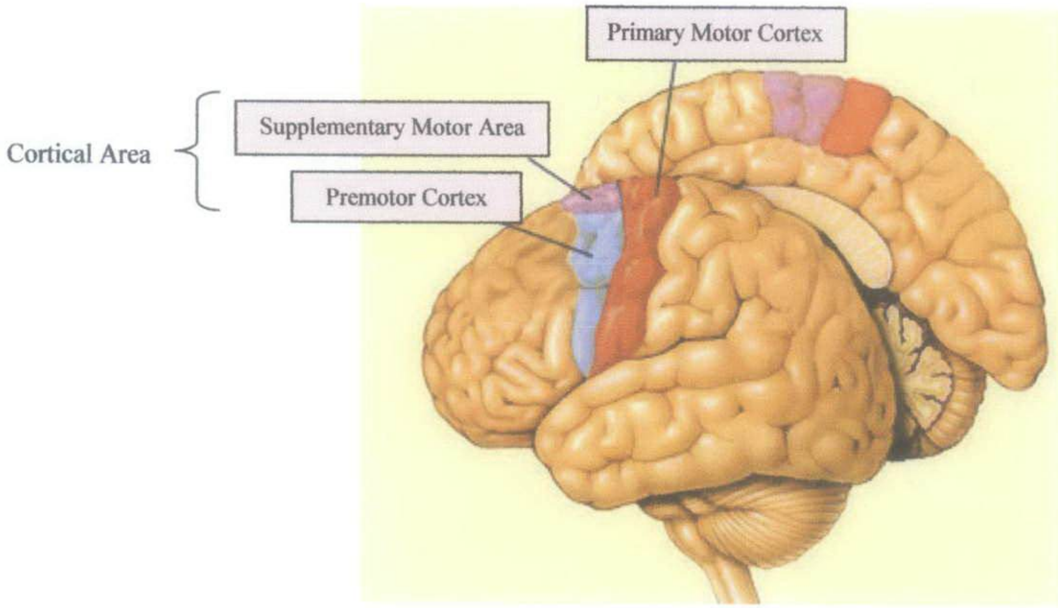


figure 22: The motor Cortex at the frontal lobe

The functions of each area are included in the table below;

Area	Description
Primary Motor Cortex	Plans and execute movements
Supplementary Motor Area	Involved in planning complex movements and in coordinating movements involving both hands.
Premotor Cortex	Guide body movements by integrating sensory information and controls the muscle that close to the body's main axis

table 5 : Functions of Motor Cortex

2.4.3.2 The Cerebral Cortex Activation

The function of brain is to produce behaviors which are movements [16]. Regions around Cerebral Cortex involved in controlling body's movements. To study how signals travel around the brain region, we need to know how the brain responds to stimulus. Figure 25 illustrates how activation travels on the Cerebral Cortex.

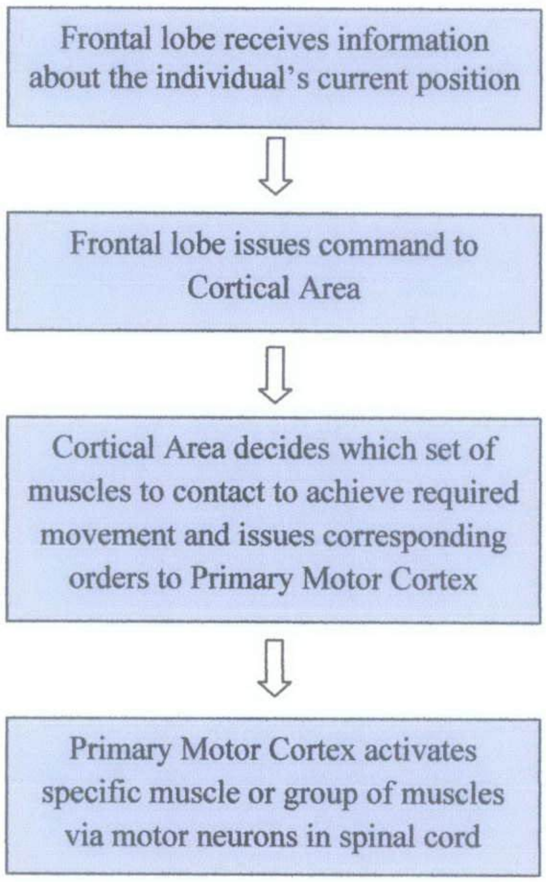


Figure 23 :General Activation Occur in the Cerebrum Cortex due to Stimulus

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

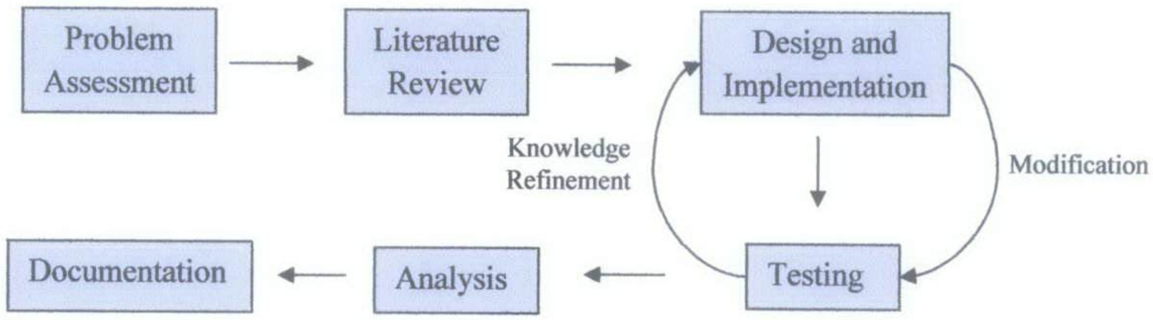


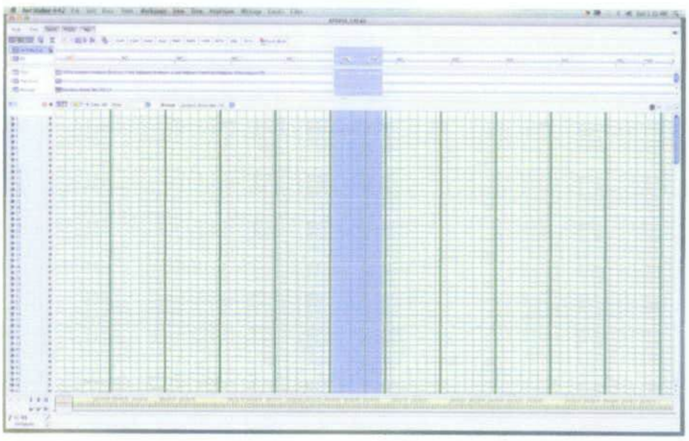
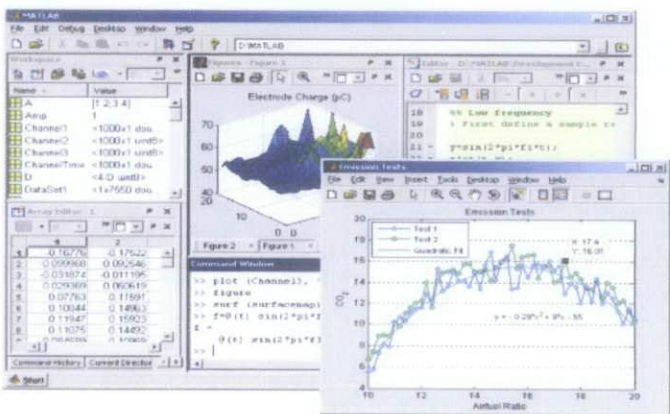
figure 24: Research methodology of this project

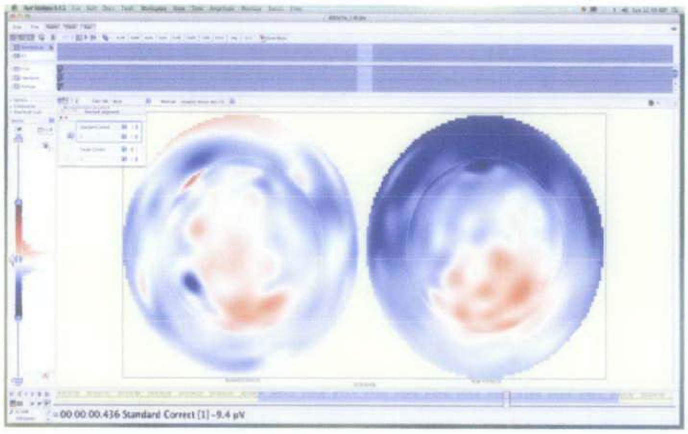
Steps	Description
Problem Assessment	Identify the problem statement. Currently, no proper motion estimation technology is available for tracking activation around brain region. Development of motion estimation system allows us to observe and study movements of brain signals.
Literature Review	Literature review on available motion estimation methods and works done so far in that area. Besides that, studies carried out related to brain anatomy especially on the structure and functions of Cerebrum Cortex.
Design and Implementation	Design a system, which estimates motion in brain topographic videos using MATLAB
Testing	Debug the system to produce reliable results
Analysis	Observe movements that occur in the brain map and relate them to the study
Documentation	Research write up and recommendations.

Table 6 :Description of my research methodology

3.2 Project Activities

Project conducted in four phases which consists of 28 weeks.

Phase	Description
One	**Literature Review** • Paper review on various Motion Estimation Methods available and works done so far in that field. • Study general brain anatomy, especially the cerebral cortex and how activation moves on brain region.
Two	**Development of System** Develop the motion estimation system based on full-search algorithm *Software : MATLAB and NETSTATION 4.4.2*  *(a)*  *(b)* *figure 25: (a) Netstation 4.4.2 (b) MATLAB*

Phase Three	**Testing and Error Correction** Testing for system reliability using small sequence of video frames. The brain topographic maps acquired from Netstation 4.4.2 *Software used : MATLAB and NETSTATION 4.4.2*  *figure 26: Brain Topographic maps generated by Netstation 4.4.2*
Phase Four	**Analysis & Application** Apply the full search motion estimation system for longer topographic maps provided by NetStation 4.4.2. Analyze the results and try to reason out the motion which occurs in the brain topographic maps. *Software used : MATLAB and NetStation 4.4.2*

3.3 Description of Project Activities

Description of Data

The topographic maps which I have been using were gathered from pervious study related to Event-Related Potential (ERP) signal analysis . Each subject participated in experiments consists of 200 trials, recording their ignorance to stimulus O and response to stimulus X. The frequency of the stimulus present is below:

Type of Stimulus	Frequency
X	40
O	160

table 7: Type of stimulus used

From the table above, the ratio of X:O is 1:4. Each subject will participate in an experiment, where X appears 40 times while O appears 160 times. Signal recorded for all 200 trials.

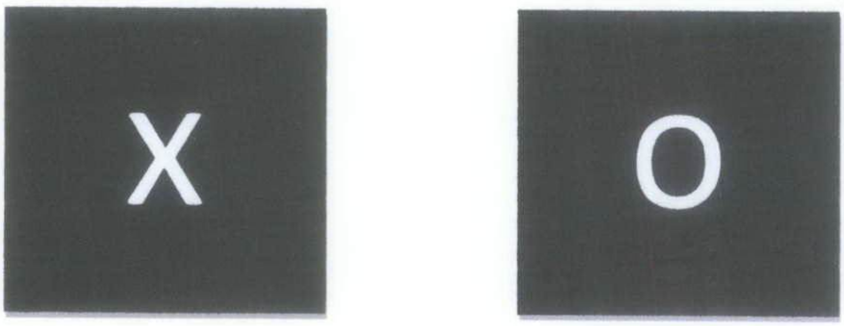


figure 27 : X and O stimulus used for past study

Since we are looking at overall activity, average response of the brain segmented into two categories; Response when X and O is present. Each response plotted as 50 seconds of topographic maps consisting five frames per second.

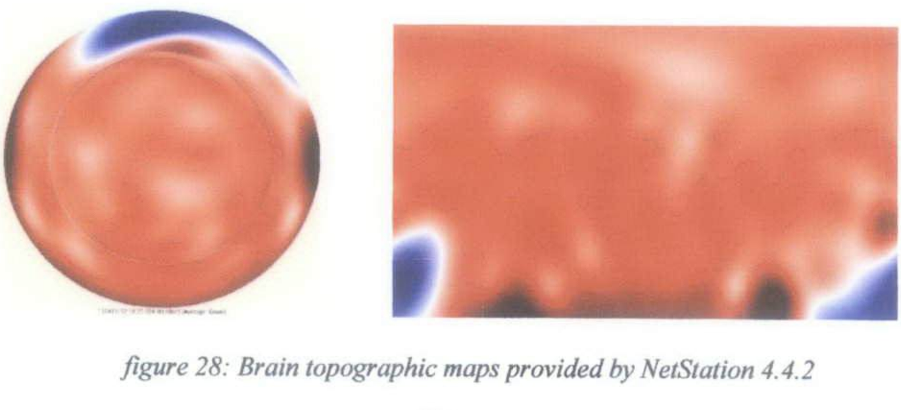


figure 28: Brain topographic maps provided by NetStation 4.4.2

3.3.1 Phase One : Literature Review

Kindly review part 3.0

3.3.2 Phase Two : Development

4.3.2.1 Difference between frames

To find how much the current frame different from the reference frame [17], we can simply take its respective pixel subtraction, given by equation;

$$Difference(i,j) = Reference(i,j) - Current(i,j) \qquad (15)$$

Where the difference computed by taking two input images and produce an output of the first image minus the respective pixel values from the second image. Besides that, we can use a single image as input and subtract a constant value from all the pixels.

$$Difference(i,j) = Current(i,j) - C \qquad (16)$$

Moreover, difference can be computed by taking absolute difference between pixel values, rather than the signed output.

$$Difference(i,j) = |Reference(i,j) - Current(i,j)| \qquad (17)$$

(a) (b) (c)

Figure 29: Example of image subtraction performed in MATLAB, (a) is the reference image, (b) is the current image and (c) is the absolute difference of (a) and (b)

3.3.2.1 Full Search Algorithm

As mentioned in the previous chapter, the motion estimation system will be based on Full Search Algorithm (FS). Figure 30 shows the range of search region.

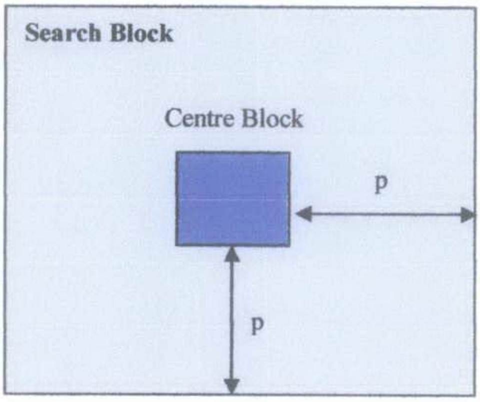


figure 30: Search parameters involved

<u>Matching Criteria</u>

In finding the matching block, FS searches the entire region specified by the neighborhood constraint for a block such that the MAD is a global minimum. The MAD selected based on the criteria below;

$$\boxed{\text{MAD} \neq 0 \text{ and Minimum}}$$

Note that if more block generates a minimum MAD, FS selects the macro block whose motion vector has the smallest displacement from the original location.

To achieve this, points checked starting at the centre of the search region. Since the maximum displacement of a motion vector in both the horizontal and vertical axis constraint to [p –p], the total number of search points used to locate the motion vector for each block is $(2p + 1)^2$ which includes the centre as well.

Therefore, I've selected p to be 7 for my study. This gives me total of 15^2 number of search points. According to *Aroh Batjaya* [18], the ideal size of the block size is 16. Using these initial parameters, I've developed my motion estimation system.

Besides that, the system should be programmed to detect overflowing such as search points exceeding the actual size of image.

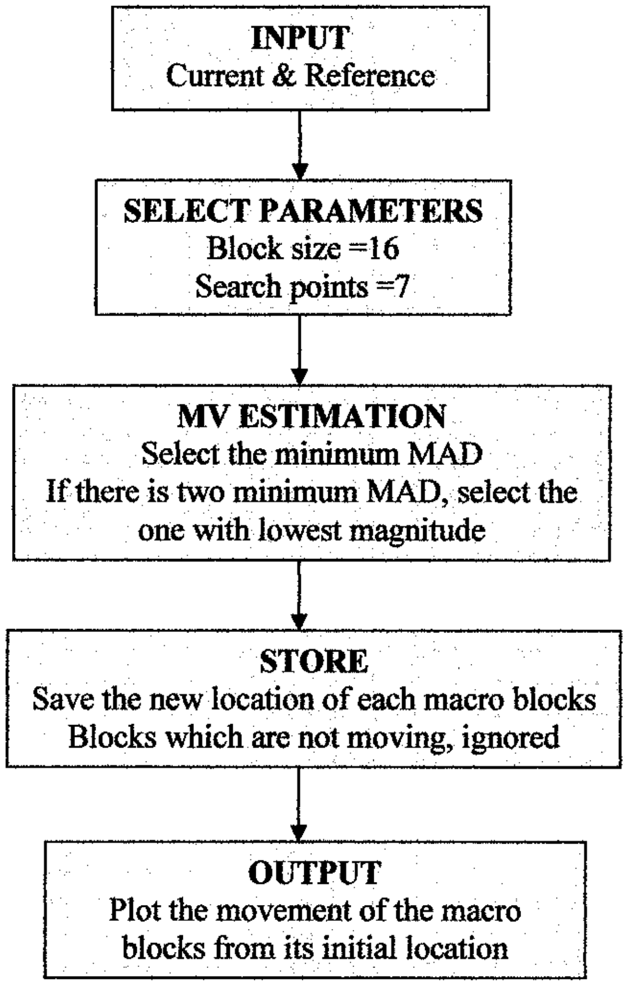


figure 31 : flowchart of the development process

3.3.3 Phase Three : Testing & Error Correction

3.3.3.1 Similar MAD's

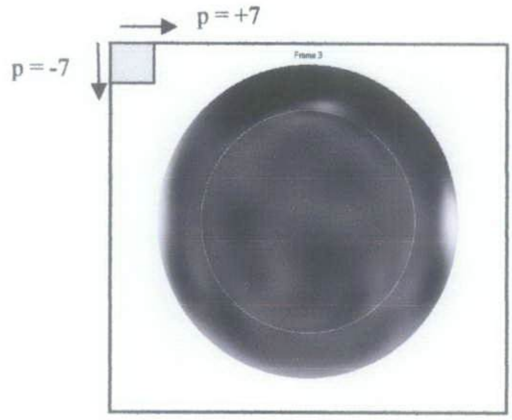


figure 32: similar MAD's due to border

When the full search algorithm searches for lowest motion at the border area, there are many similar MAD's detected. Most of them are zero. We aware that zero occur only when there is no motion. Therefore the full search algorithm selects the nearest point as the result which is an error.

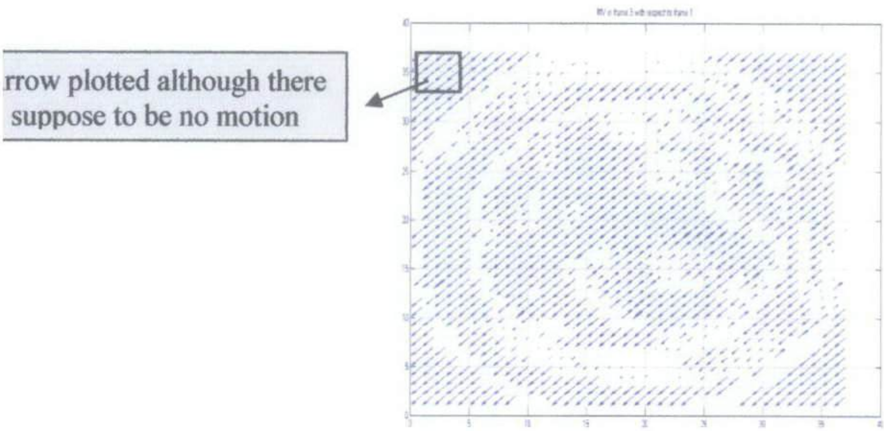


figure 33: Error due to similar MAD's

Through manual screening, it is noted that the border consists of [250 252] pixel values. I've converted all of them to 250. Then, the full search algorithm modified to search at the centre location first before proceeding to other locations. If it results zero, the actual location will be considered as the new location. Therefore, this macro block considered to be stationary. As we know, border is a stationary element in an image.

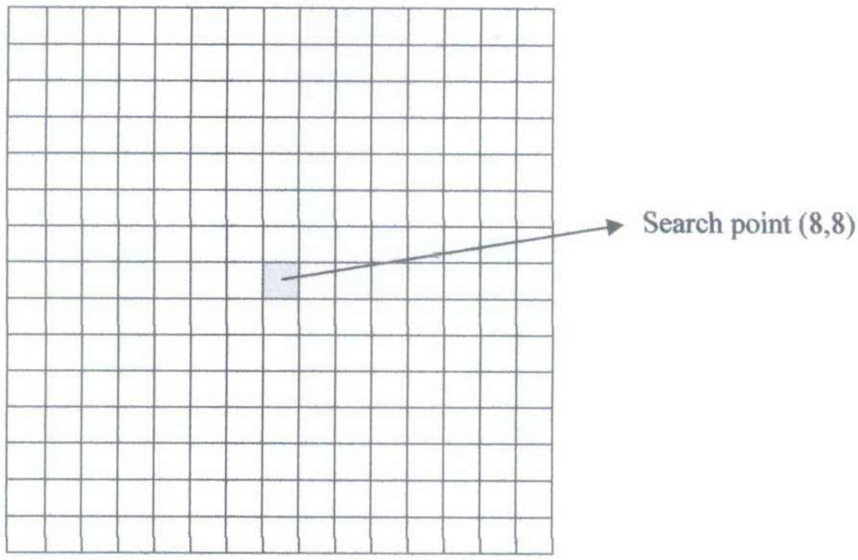


figure 34 : Centre for both reference and current macro block

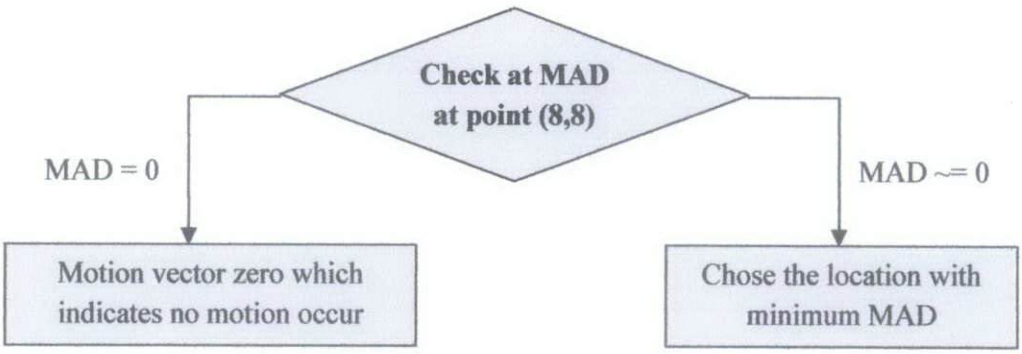


figure 35 : Flowchart of stationary macro block

3.3.3.2 White Circle

At the middle of the input image, there is a white circle. When Full search algorithm performed on this part, this area detected as no motion. Therefore, I've applied neighborhood averaging method to replace the 255 pixels with two by two neighborhood average pixels.

90	91	93
94	255	95
99	97	96

(a)

90	91	93
94	94	95
99	97	96

(b)

figure 36 : centre value replaced with neighborhood averaging

Where,

(x3,y3)	(x7,y7)	(x4,y4)
(x2,y2)	(x0,y0)	(x1,y1)
(x5,y5)	(x8,y8)	(x6,y6)

figure 37 : Location of pixel 255 represented by (x0,y0)

(x_0, y_0) can be replaced by using the equation below;

$$(x_0, y_0) = \frac{1}{8}\sum_{i=1}^{8}(x_i, y_i) \qquad (18)$$

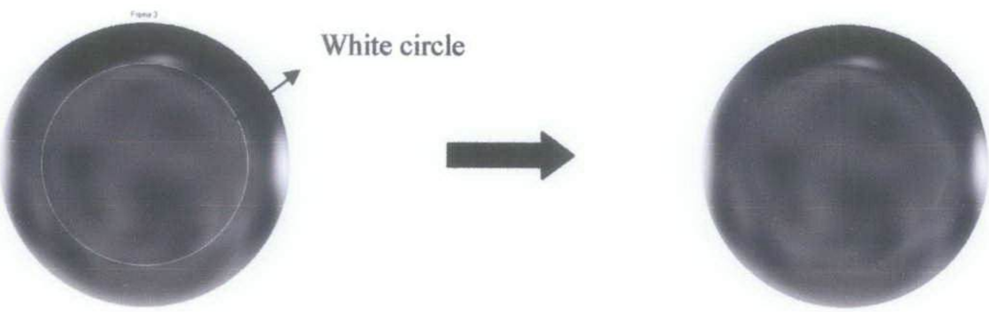
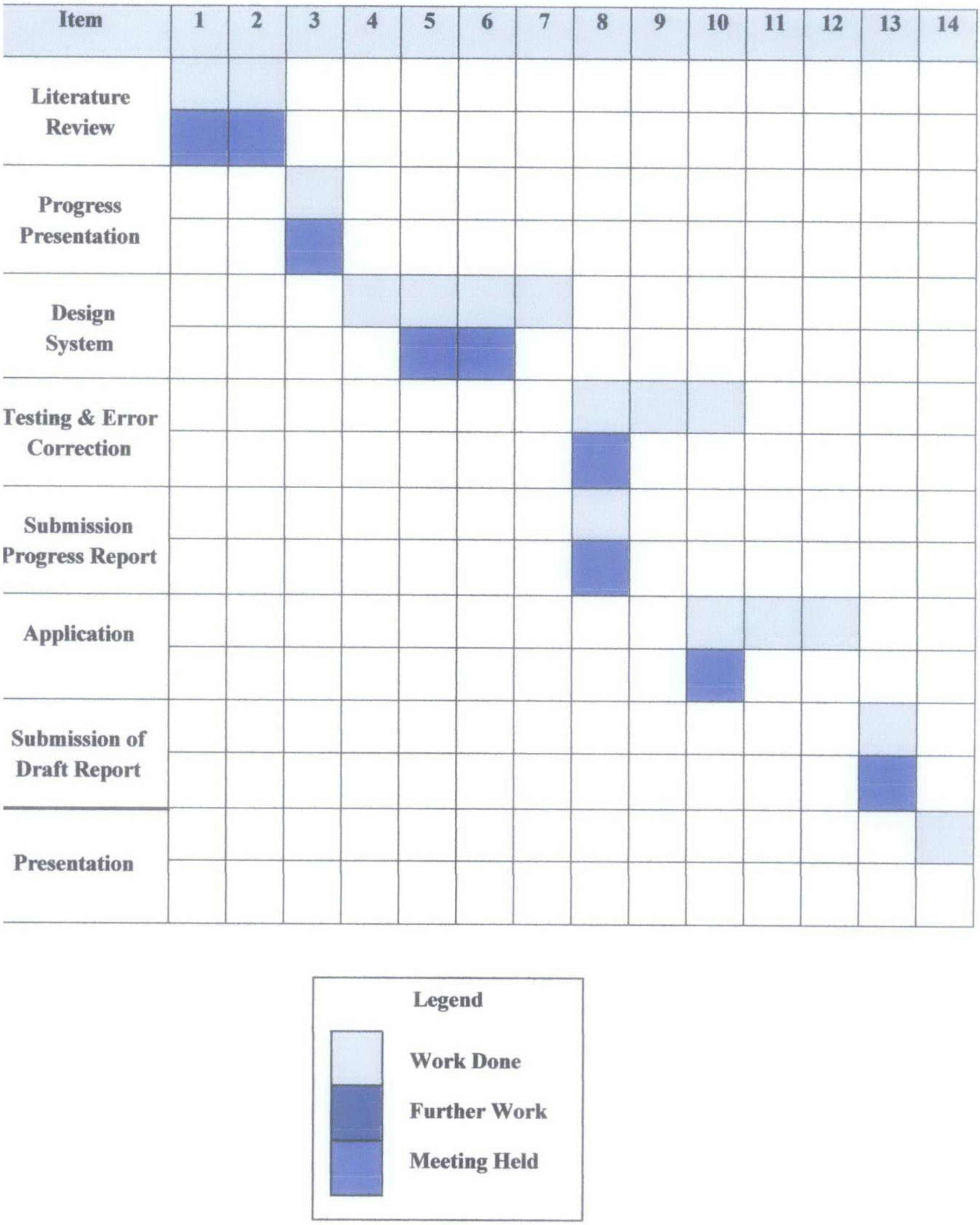


figure 38 : Before and after neighborhood averaging

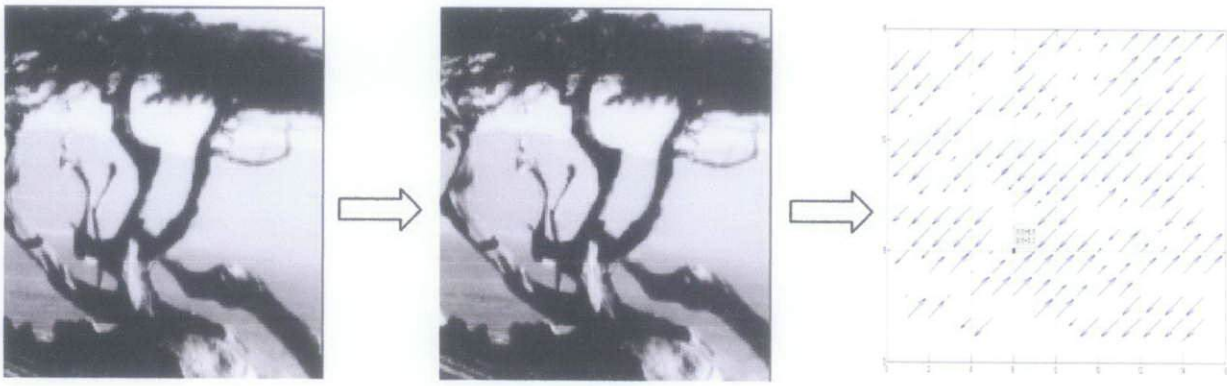
The Gantt Chart for FYP2



CHAPTER 4

RESULTS AND DISCUSSION

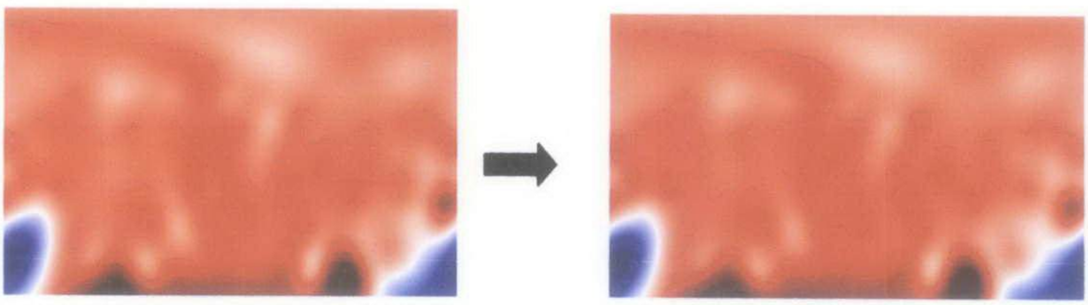
Before testing on the actual brain topographic maps, the Full Search Algorithm tested on sequence of video frames. Figure 38 shows the test frames used.



(a) (b) (c)

figure 39 :Motion vector occur in frame (b) with respect to frame (a) with [10 10] block size

First trial on brain topographic maps.



Reference Frame ***Frame 25***

figure 40: Arrows indicates movement

The results above is for tracking [30 30] macro block from the bottom left of the reference frame to frame number 25. The arrow indicates the movements occur from the first frame to 25th frame.

4.1 Preprocessing

Conversion RGB → Gray

To reduce the complexity of processing, I've used the Gray images of the topographic maps. Since *Netstation 4.4.2* provides me with one, conversion in MATLAB still preserves most of the details of these images.

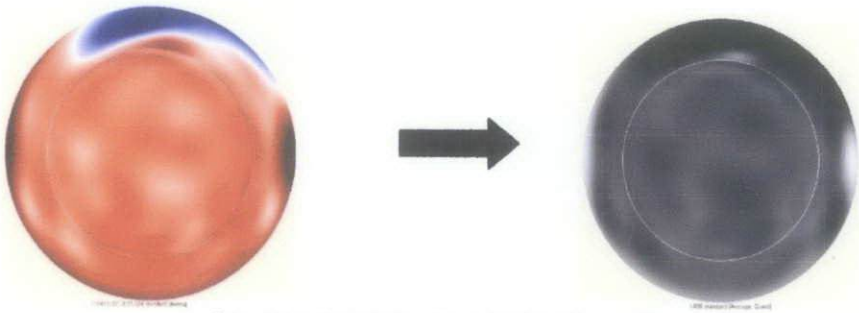


figure 41 : Conversion from RGB to Grayscale

Neighborhood Averaging

After screening through the brain topograhic maps, I've identified the cordinates of the white circle. This cordinates undergo neighbourhood averaging.

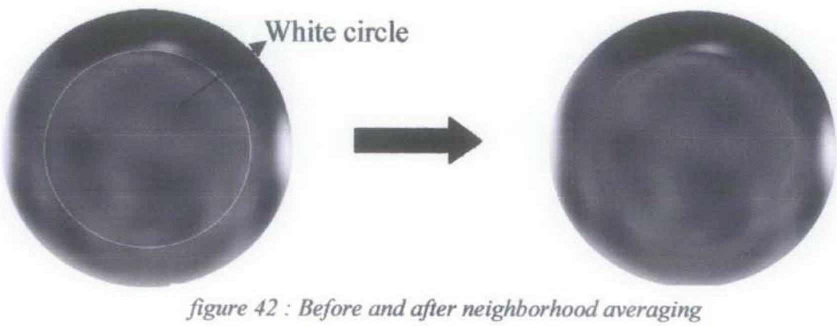


figure 42 : Before and after neighborhood averaging

Cropping

To avoid unnecessary processing, I've cropped the sequence of images to desired dimension.

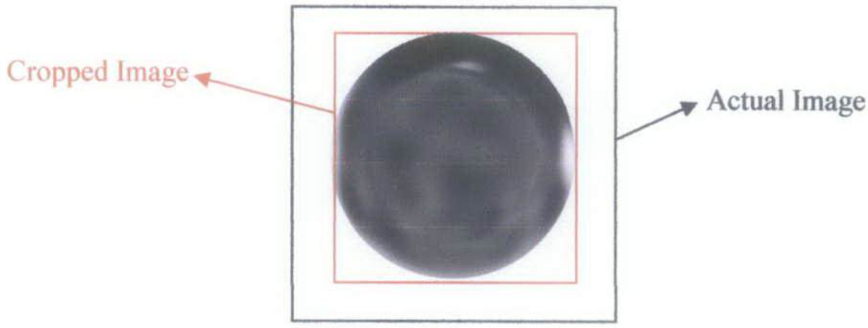


figure 43: Image cropped according to specified dimension

Image Subtraction

Before processing, the difference between reference and current frame evaluated.

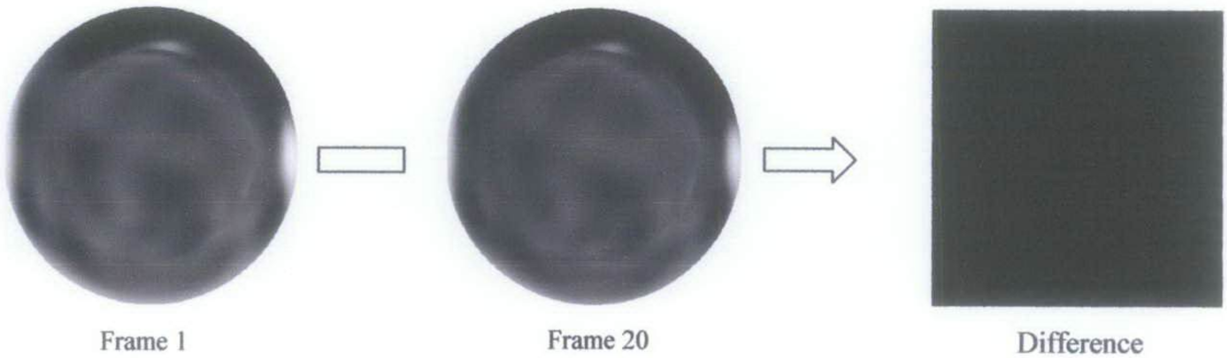


figure 44 :Image Subtraction performed on brain topographic maps

4.2 Behavior of Brain Signals

As discussed in the literature review, in human brain, planning for any given movement done in forward portion of the frontal lobe. This cortex receives information about the individual's current position from organs such as eyes [19].

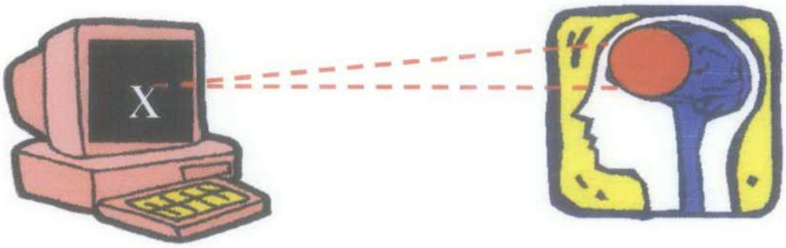


figure 45: Frontal lobe receive information from the eyes

Figure 44 illustrates how the frontal lobe activates due to stimulus. Then, frontal lobe issues commands to Cortical Area. Here, decisions made on which set of muscle responsible to achieve required movement. As we have instructed our participant to respond to X and ignore O, the muscle movement involved when there is need for participant to respond. Then, Cortical Area issues command to Primary Motor Cortex. Here, specific muscle or groups of muscle activated via the motor neurons in the spinal cord. The muscle movement is also associated with the parietal lobe. Note that participant respond through pressing specific keys on key board. Figure 45 shows how signals travel from frontal lobe to motor control cortex and parietal lobe. In this example, the human brain responds by blinking eyes. Therefore, signals travel from parietal lobe to eye muscles.

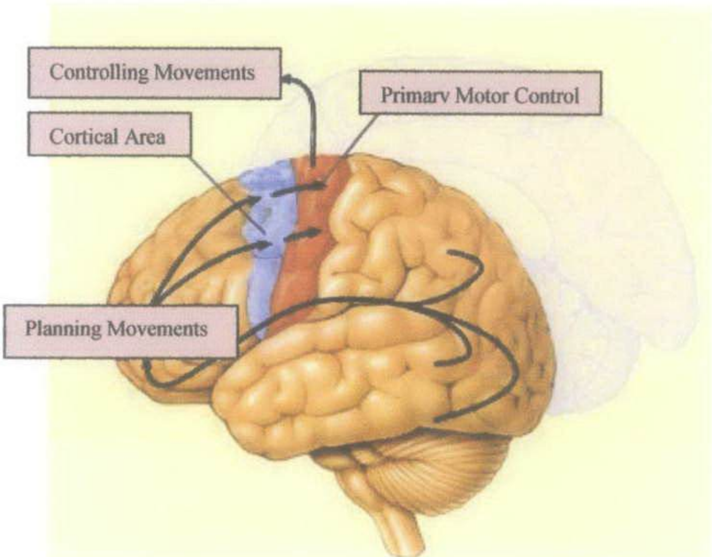


Figure 46: Movement of signals due to stimulus

4.3 Results

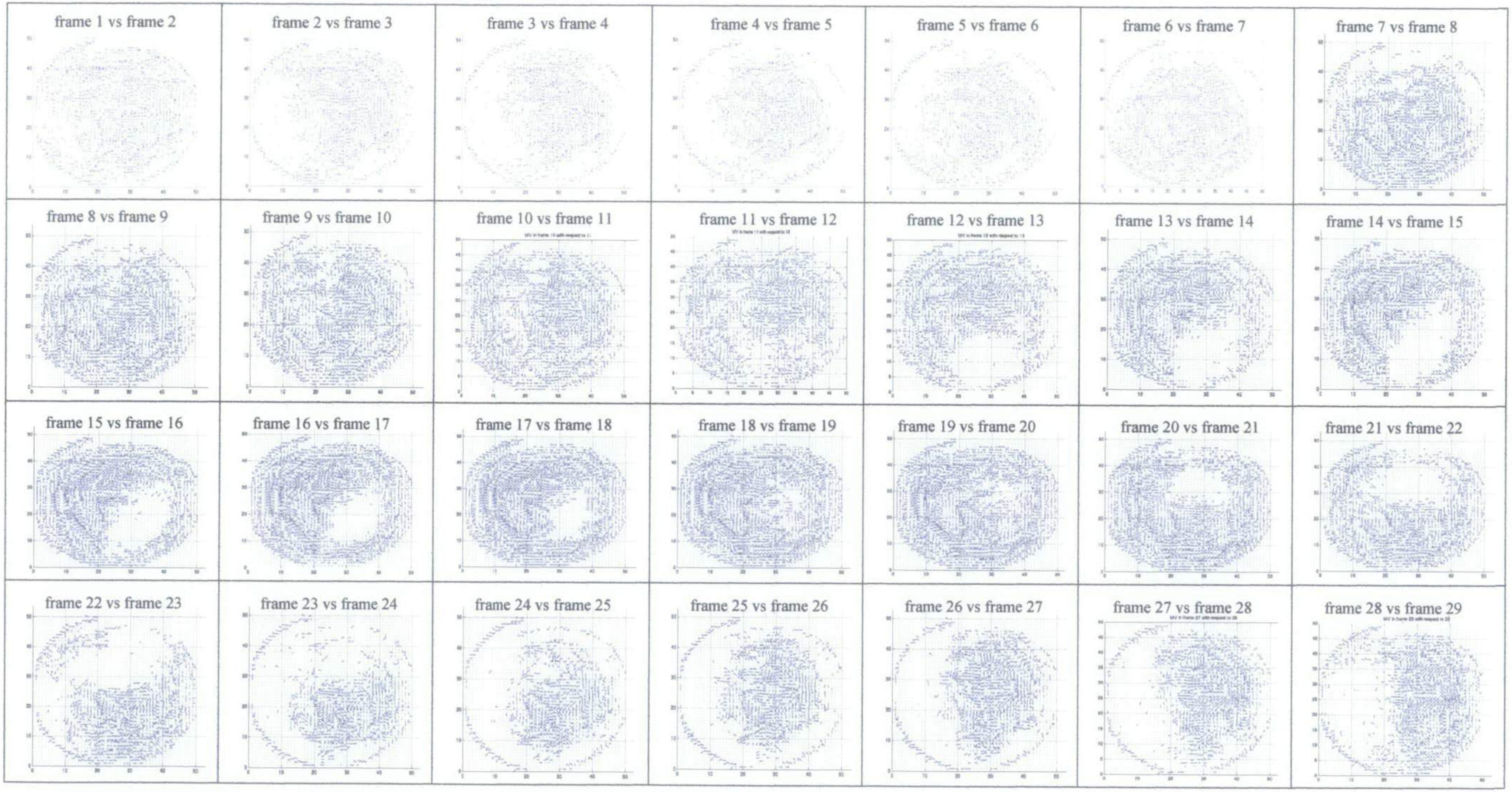


figure 47 :Activation occur on the brain region for every 200ms (total of 4.8 sec consists of 29 frames) when stimulus O is presented to Subject 6

figure 48 :Activation occur on the brain region for every 200ms (total of 4.8 sec consists of 29 frames) when stimulus X is presented to Subject 6

4.3.1 Analysis

When there is no activation in certain region, no motion is detected at the corresponding region;

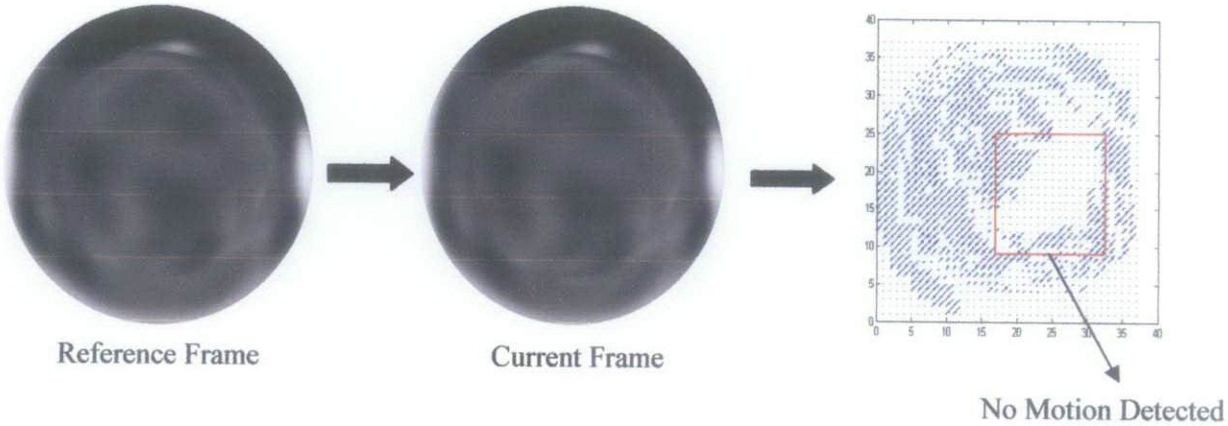


Figure 49 : Example of regions with no activation at time t

The motion estimated used to reason out the movement of signals on the brain region

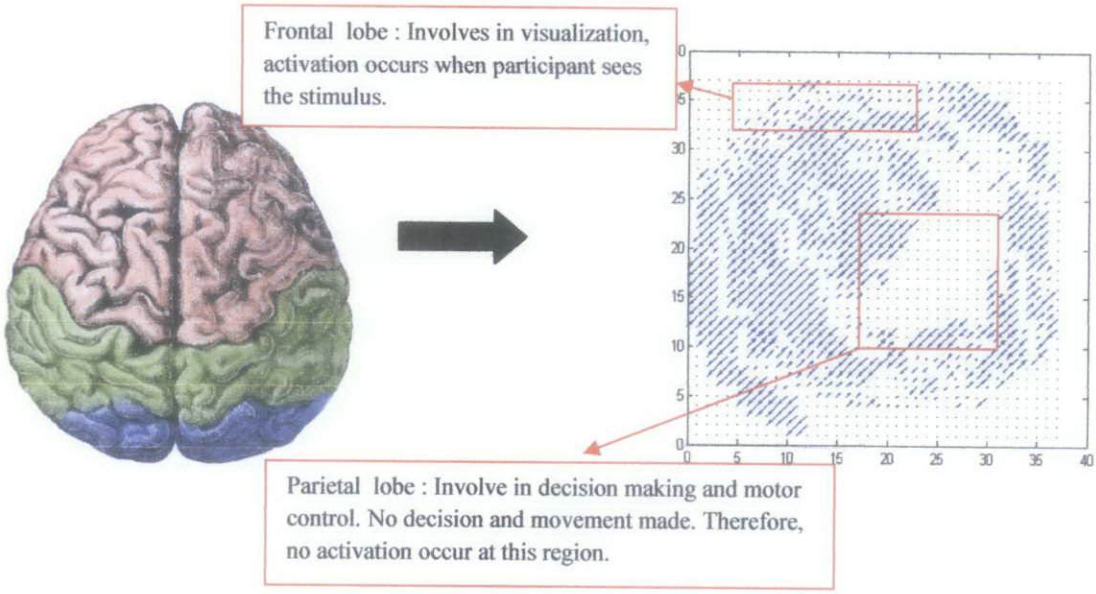
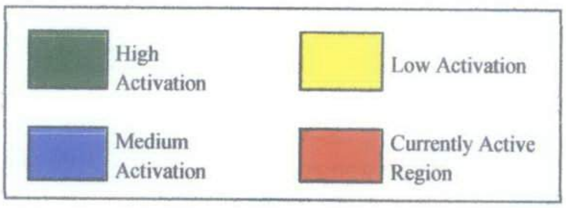


Figure 50 : Resulting MV map compared with actual brain structure to study the behavior of motion occur

Table 8 shows the observation of events which occurs in figure 46. Note that, given legend;



Based on Results in figure 47, we can observe that;

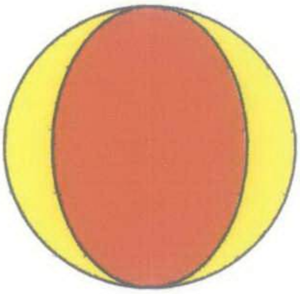
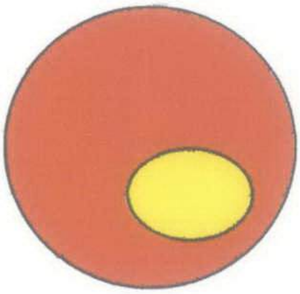
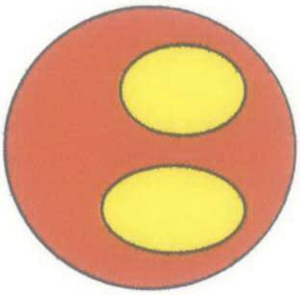
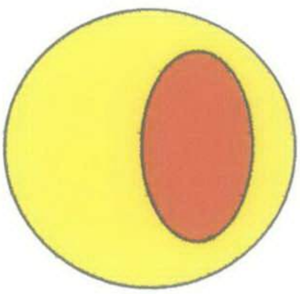
Frame Sequence	Observation
Frame 1- Frame 8 	Signal moves from temporal and occipital lobe to the centre of the brain. Activation in frontal lobe decreased after 0.6 seconds. Temporal and occipital lobe becomes active again after 1.2 seconds. **Possible event:** Since no response is needed, frontal lobe remains inactive (no planning is required). Occipital lobe process information since O is a visual stimulus.
Frame 9 - Frame 15 	All region active from 1.8 second to 2.4 second. After 2.4 second, parietal lobe remain inactive. **Possible event:** Although Stimulus appears to be O, the brain still processing visual information. Since there is no movement required, the parietal lobe is not active.
Frame 16 – Frame 22 	Parietal lobe remain inactive till second 3.6. All region active for 4 ms. After 4 second, no activation occur in central motor control and frontal lobe. **Possible event:** Parietal lobe remains inactive since there is no movement required. Frontal lobe didn't plan for any movement. Therefore, central motor control didn't activate any muscle
Frame 23 – Frame 29 	Parietal lobe and central motor control remain inactive till 4.4 second. After 4.4 second, right hemisphere becomes active. **Possible event:** Similar to previous analysis, since no decision making and muscle movement required, parietal lobe and central motor control remain inactive.

Table 8 : Observation and description of event occur in figure 47

Based on Results in figure 48, we can observe that;

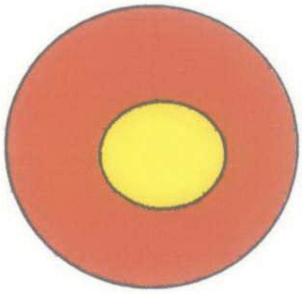
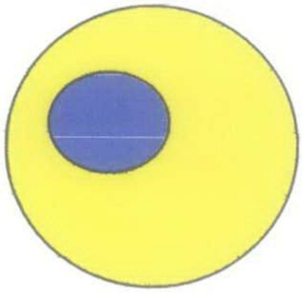
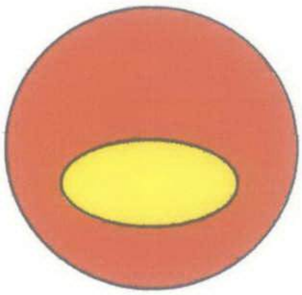
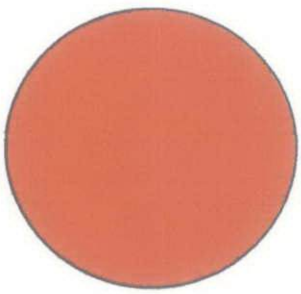
Frame Sequence	Observation
Frame 1- Frame 8 	For the first second, all regions are very active. After 1.2 seconds, activation decreased in the parietal lobe. **Possible event:** When subject starts to concentrate on the stimulus X, frontal lobe captures the information received. Occipital lobe process this information since it is a visual stimulus.
Frame 9 - Frame 15 	Small region of parietal lobe and central motor is active. **Possible event:** Since subject need to respond to stimulus, central motor control activates necessary muscle to make the movement.
Frame 16 – Frame 22 	Activation moves from right hemisphere to left hemisphere. Parietal lobe remains active. Frontal and occipital lobe starts to get active **Possible event:** The brain is processing information received from frontal lobe. Processing is done in occipital lobe. Frontal lobe plans for movement while parietal lobe makes necessary decision and activates muscle movement.
Frame 23 – Frame 29 	All regions are very active **Possible event:** Similar to the previous event, brain receives information about the stimulus. Subject aware of required movement. Frontal lobe plans for type of movement need to be done and pass this info to the central motor control. Here, specific muscle activated in order to make the pre-planned movement.

Table 9 : Observation and description of event occur in figure 48

Another analysis can be done is by taking frames per second. As mentioned earlier, the brain topographic maps processed in this project consist of five frames per second. Figure 47 and figure 48 illustrates frames processed in actual sequence, taking pervious frame as reference and current frame as target frame. Figure 50 shows the difference between all sequence processing and per second processing.

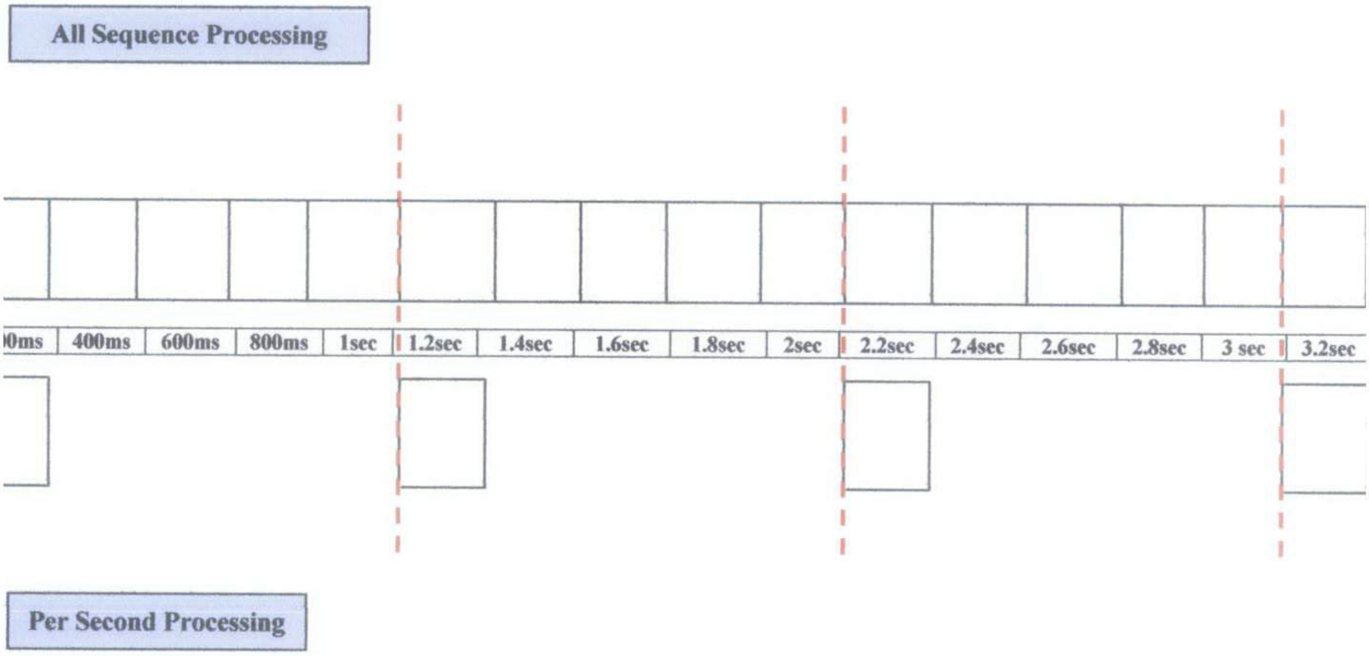


figure 51 : Different in frame selection between sequence processing and per second processing

All sequence processing is when MV estimated for all sequence of brain topographic maps available in the video. For example, MV in frame 400ms computed with respect to frame 200ms and same process continue for other frames.

Per Second processing is when MV estimated for selected frames only. For my project, I've considered taking the first frame in every second to be processed. For example, MV in frame 1.2 sec computed with respect to frame 200ms and same process continues for other frames.

Results for per second processing is included in figure 52 and 53. However, motion vector detected doesn't show any pattern occurring. Many issues can be considered here. Among the possibility is considering brain signals moves rapidly where there might be lose of information if we compare frames with bigger gaps.

Therefore, this project continued by applying all sequence processing (as illustrated in figure 47 & figure 48). Results for other subjects are included in Appendix I and Appendix II.

From here, we learned that there are difference in activation occurring in brain region due to stimulus X and O. Table 10 show the difference occur;

Standard, O	Target, X
Less activation in Parietal lobe and Central Motor Control region	Parietal lobe and Central Motor Control region are very active

table 10 : Difference between activation occur in stimulus X and O

Activation on Brain Region during Stimulus O presented to Subject 6

figure 52 : Motion estimated on brain topographic maps gained from subject 6 during stimulus O where motion tracked for every frame in the first second

Activation on Brain Region during Stimulus X presented to Subject 6

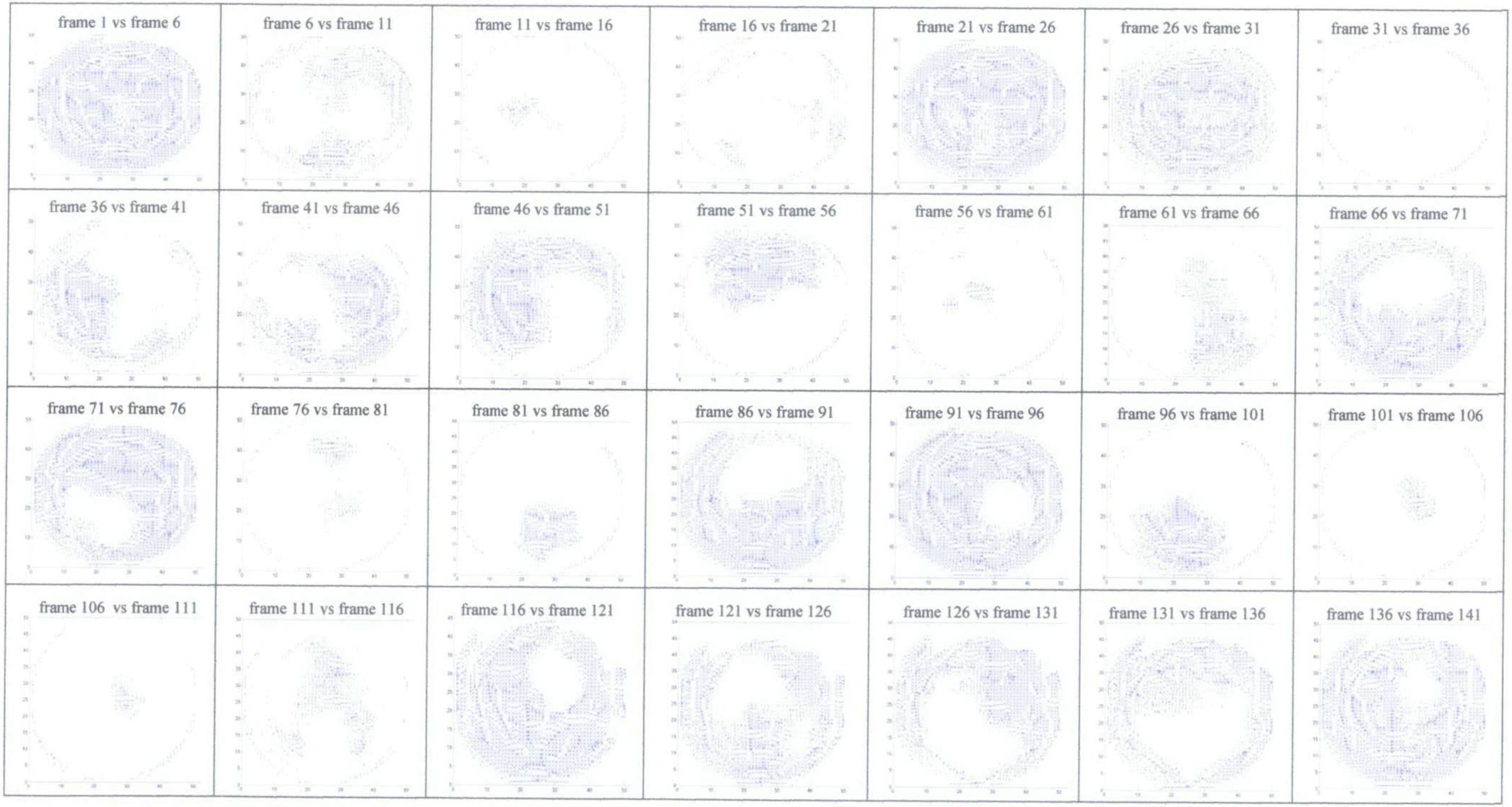


figure 53 : Motion estimated on brain topographic maps gained from subject 6 during stimulus X where motion tracked for every frame in the first second

CONCLUSION

Currently, I'm in the final phase of this project, where I believe human brain is the most complex biological system. Motion estimation is an interesting analysis of tracking movements of signals around brain region. Although time consuming, Full Search Algorithm is an efficient method for studying behaviors of activation around the brain region.

Recommendation:

Multiple displacements

There a few problems I've encountered at the final stage of my project. Among the major issue is the spreading of signals from one location to multiple locations. Figure 50 shows how one macro block moves from one location to three different locations in the current frame.

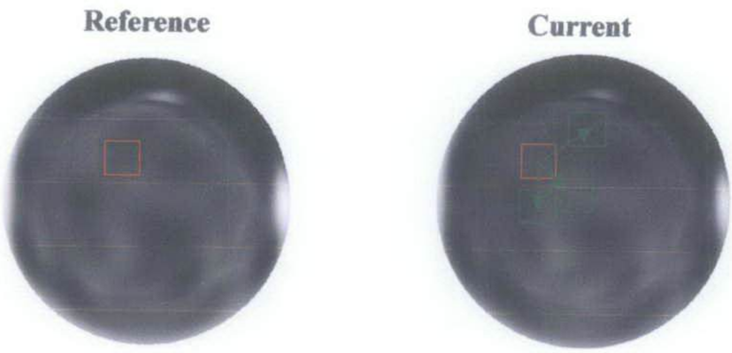


figure 54: Sometimes, the reference block moves to multiple locations on the current block

It is possible for multiple displacements to occur in brain topographic maps since brain signals are connected from one region to another. Figure 51 shows how brain signals can be tracked up to multi levels.

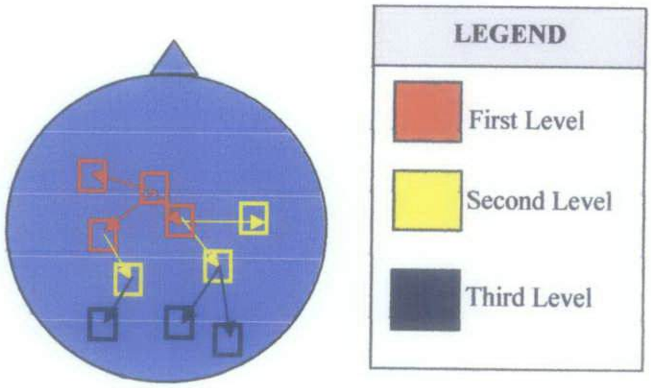


figure 55: Possible ways to plot Multi level movements which occurs in Brain Topographic Maps

Track Signals Corresponding to Their Locations

Signals tracked from various locations around the brain region. Specifying their locations allows us to observe their movements from initial location to final location. This can be done through color mapping. Mapping the vectors into different color allows us to track these behaviors. Figure 52 shows possible color mapping done to differentiate brain structures.

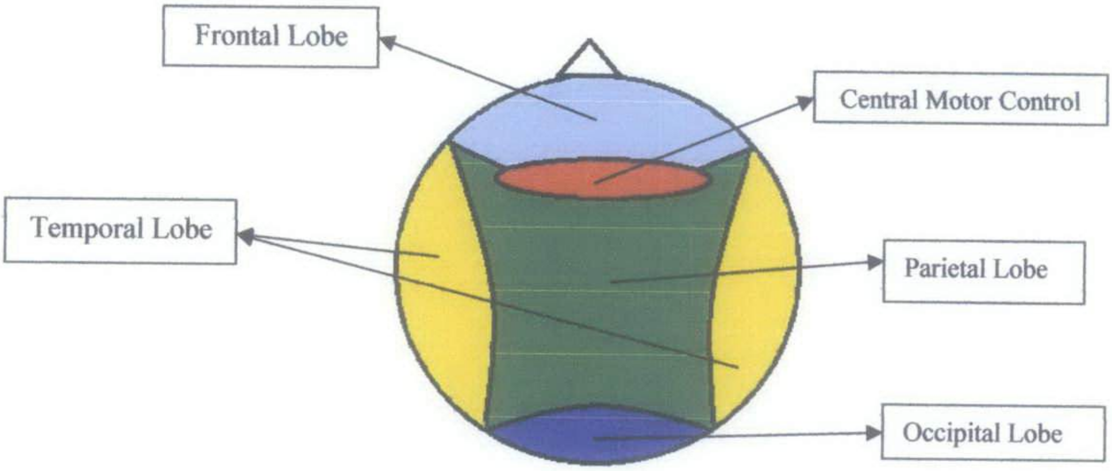


figure 56: Colors assigned according to brain structure

Hybrid Block Matching Algorithm

Combining methods and algorithms able to improve accuracy. Here, I would like to propose a matching approach by taking into account edge information and color information [20] of brain topographic maps. Note that ignorance to edge feature results error especially where intensity changes with small difference. Besides that, color measurement using Optical Flow Algorithm able to enhance estimation of matching criteria for block matching technique. In [21], it is justified that Optical Flow uses details of intensity and color information where even a very small changes within a threshold will be detected.

Therefore, the propose method will have matching criteria such as;

(a) Edge Detection

(b) Color Measurement

(c) MAD

Motion Estimation using 3D Brain Topographic Maps

Other discovery I've made is the 3D topographic functions available in *Netstation 4.4.2.*

For continuation of this project, we may consider of utilizing the 3D tools in NETSTATION 4.4.2 for estimating motion. Note that this 3D tool gives details of brain structure clearly. Therefore, color mapping will be unnecessary.

3D Brain topographic maps

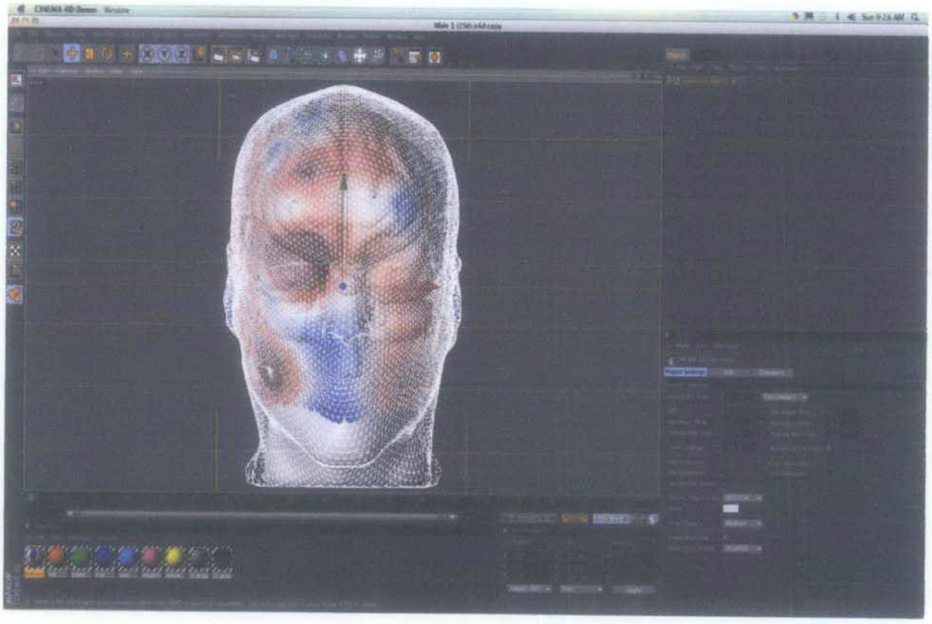


figure 57: 3D topomap provided by CINEMA 4D application

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[2] M.Teplan
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Institute of Measurement Science, Slovak Academy of Sciences,
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Appendix I - Activation during Stimulus O

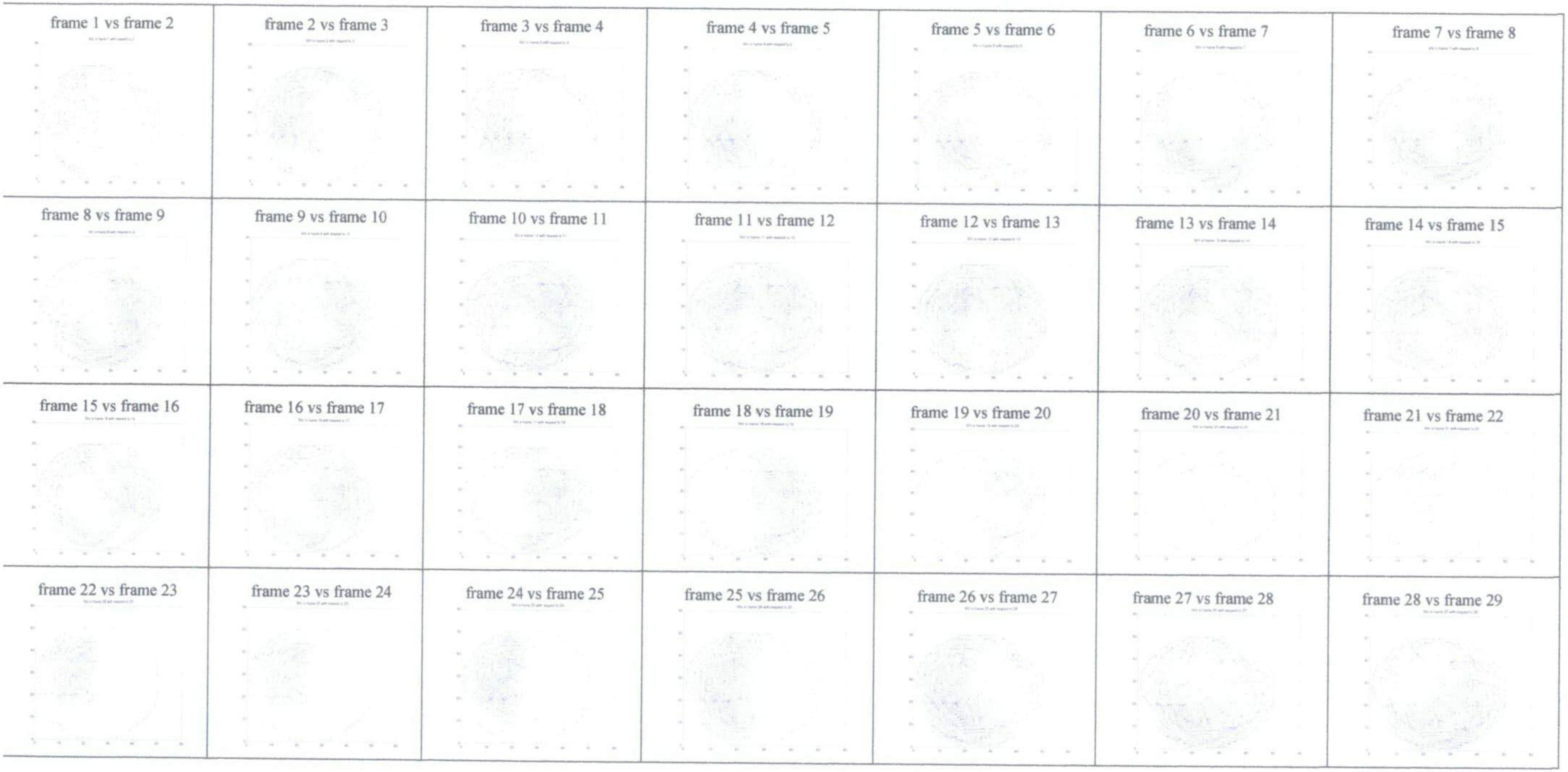

figure 58 : Activation occur in brain topographic maps for Subject 1

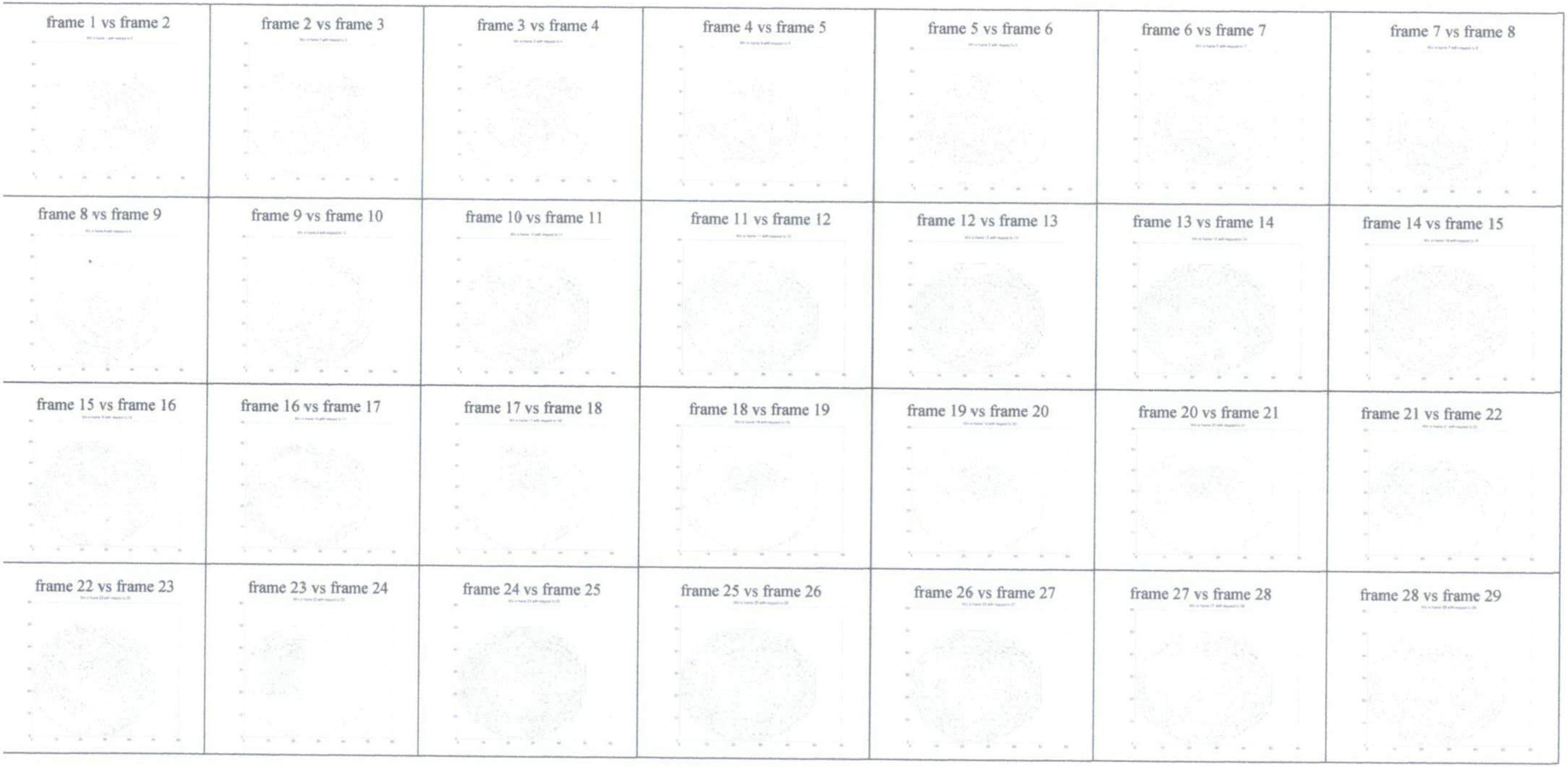

figure 59 : Activation occur in brain topographic maps for Subject 2

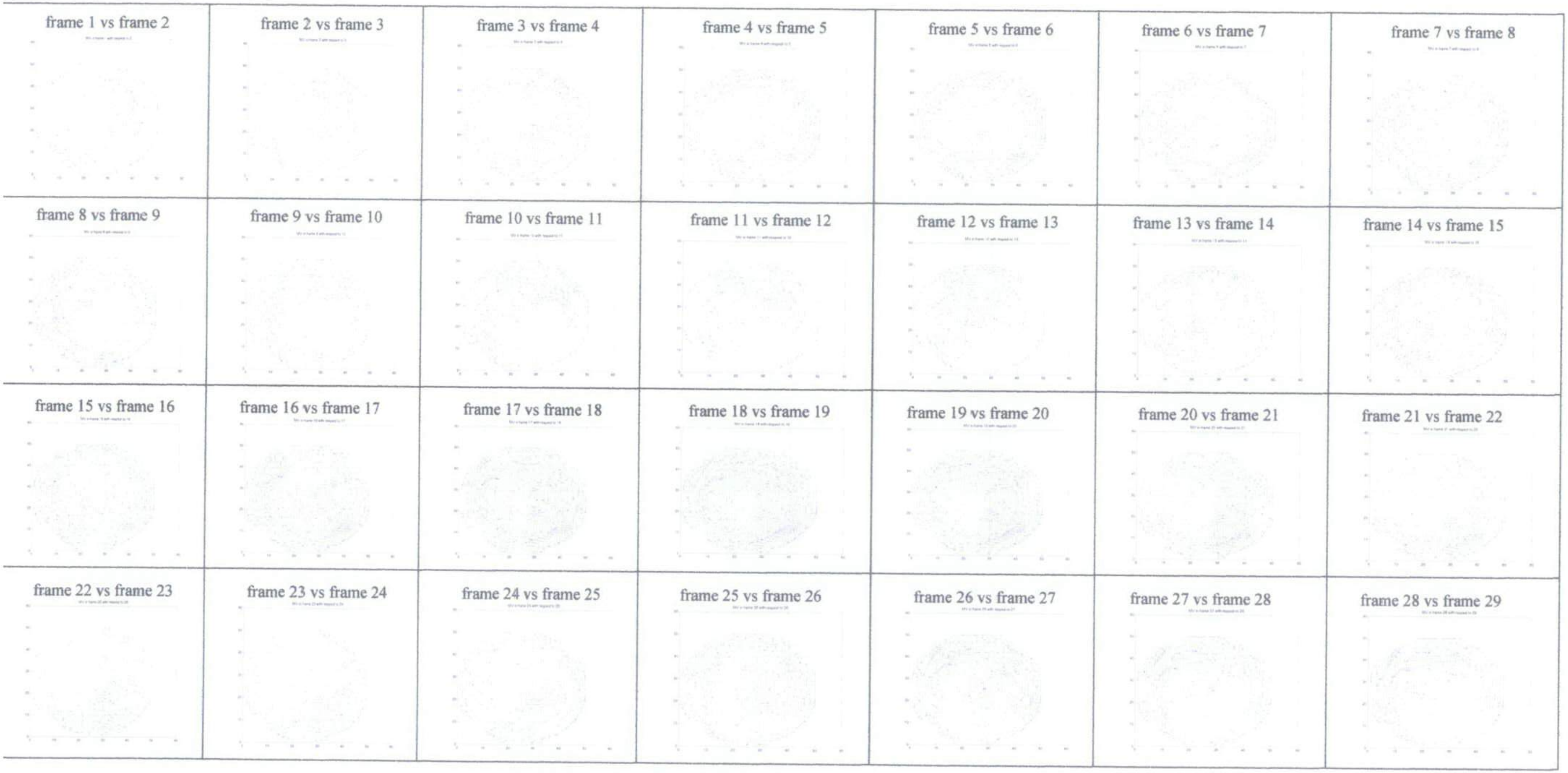

figure 60 : Activation occur in brain topographic maps for Subject 3

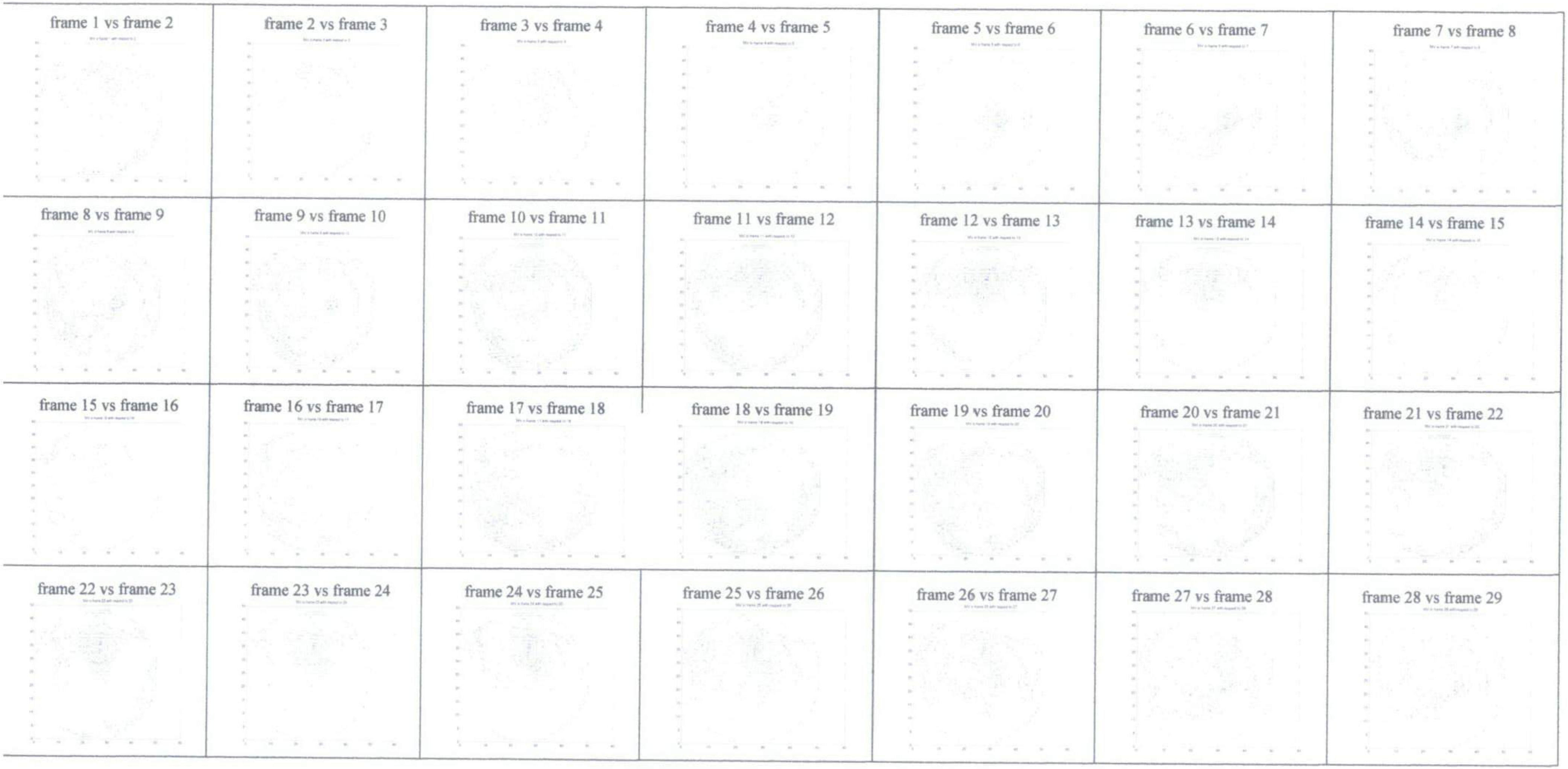

figure 61 : Activation occur in brain topographic maps for Subject 4

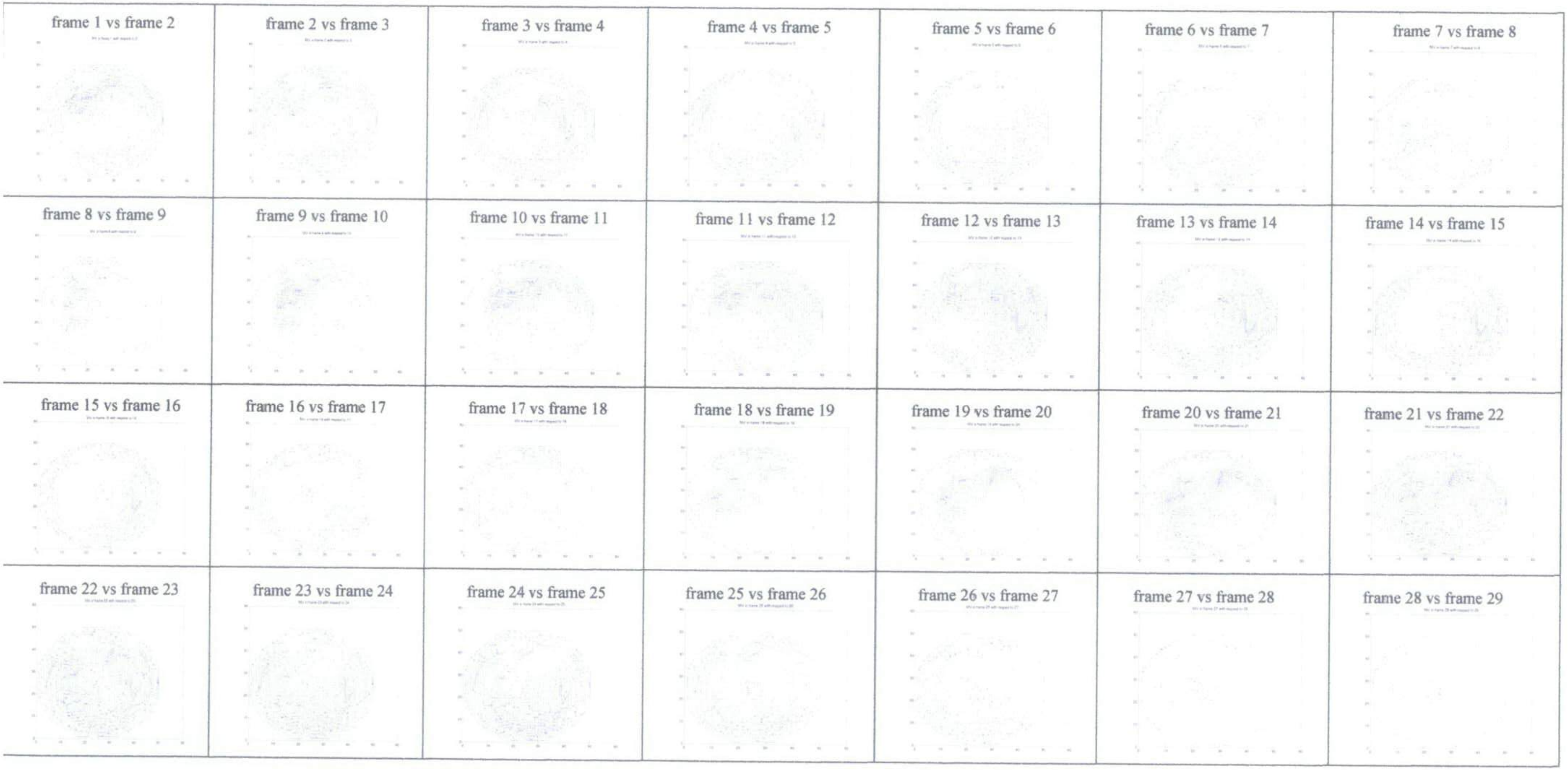

figure 62 : Activation occur in brain topographic maps for Subject 5

figure 63 : Activation occur in brain topographic maps for Subject 7

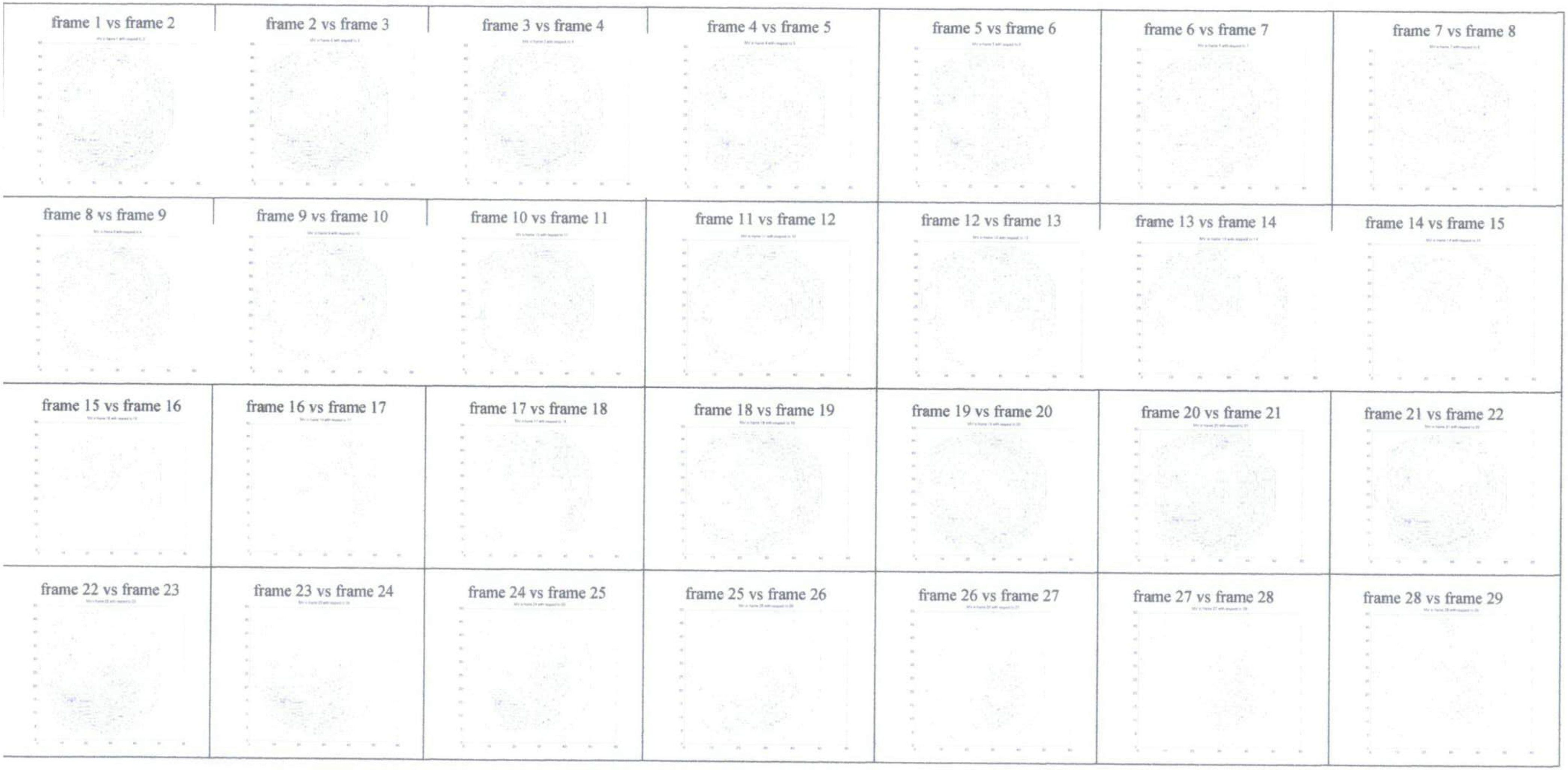

figure 64 : Activation occur in brain topographic maps for Subject 8

figure 65 : Activation occur in brain topographic maps for Subject 9

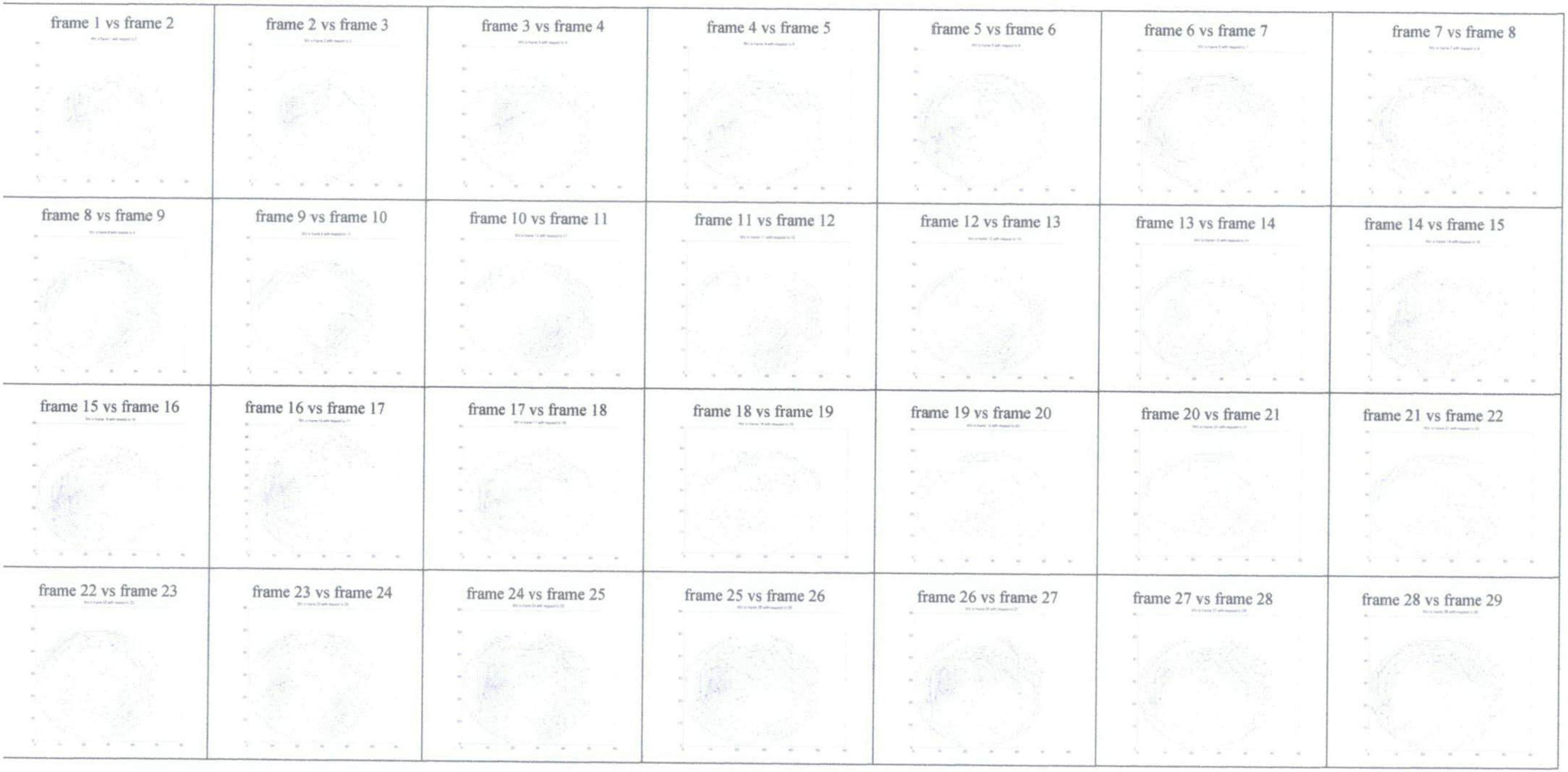

figure 66 : Activation occur in brain topographic maps for Subject 10

Appendix II - Activation during Stimulus X

figure 67 : Activation occur in brain topographic maps for Subject 1

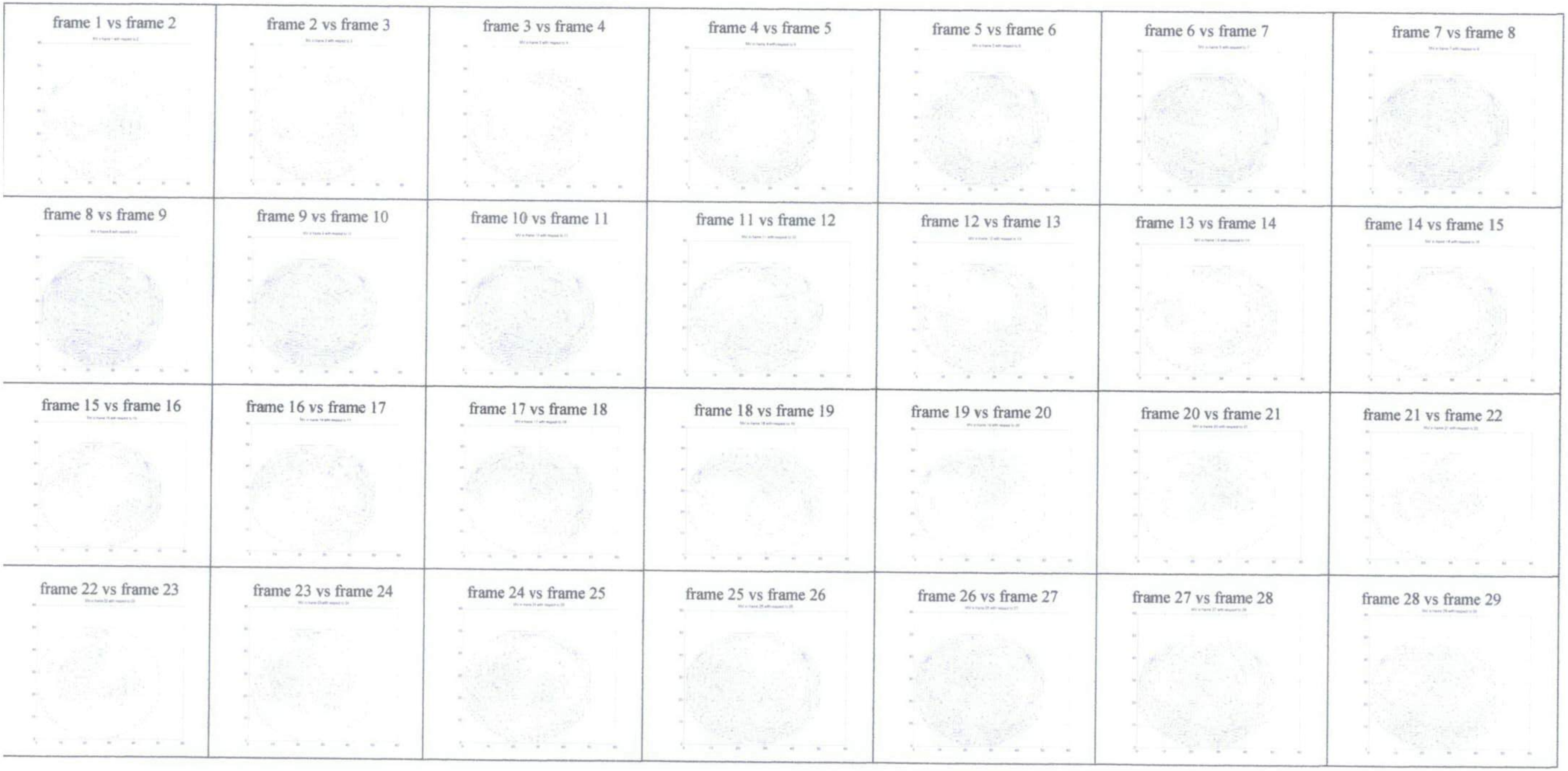

figure 68 : Activation occur in brain topographic maps for Subject 2

figure 69 : Activation occur in brain topographic maps for Subject 3

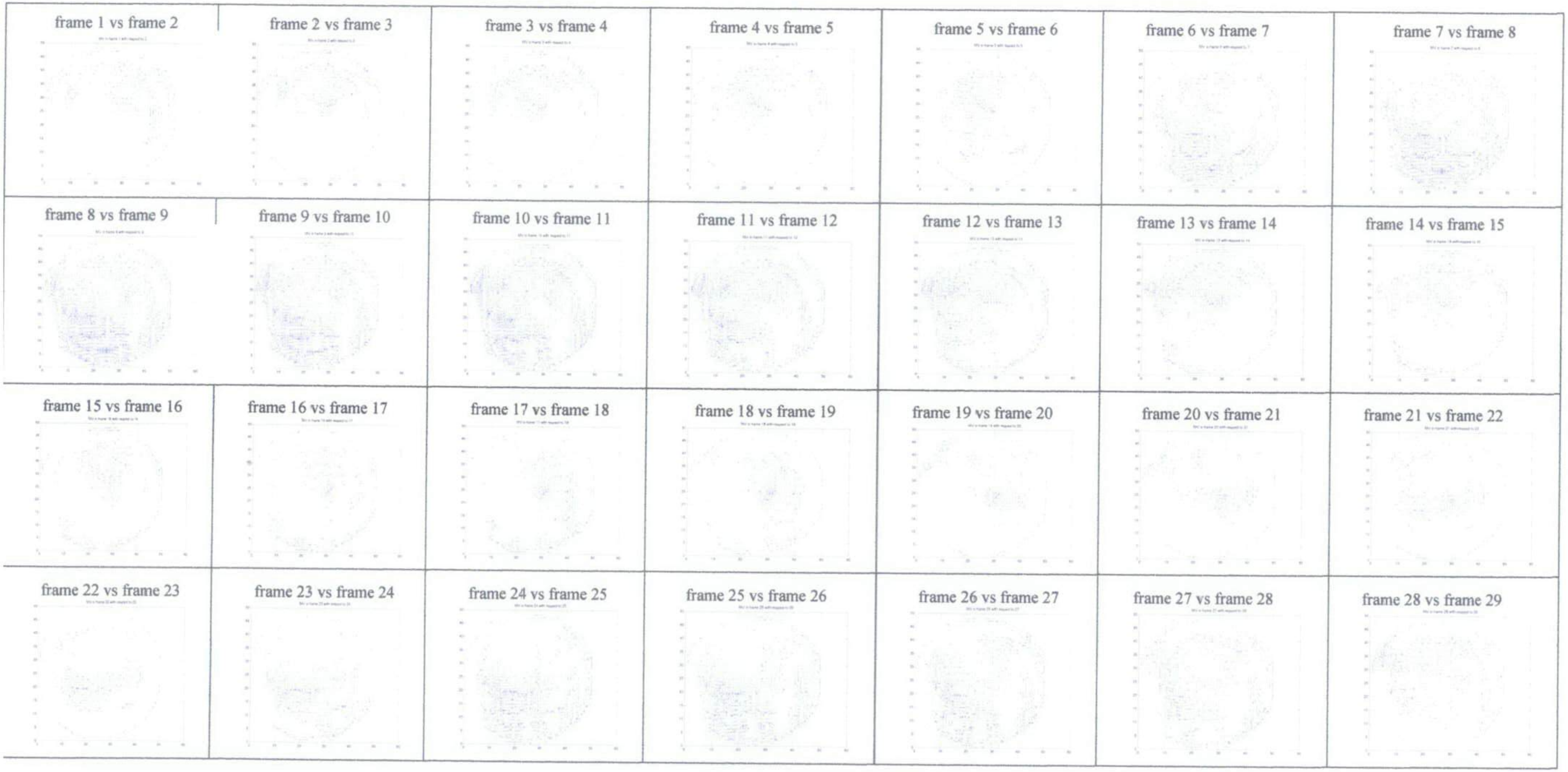

figure 70 : Activation occur in brain topographic maps for Subject 4

figure 71 : Activation occur in brain topographic maps for Subject 5

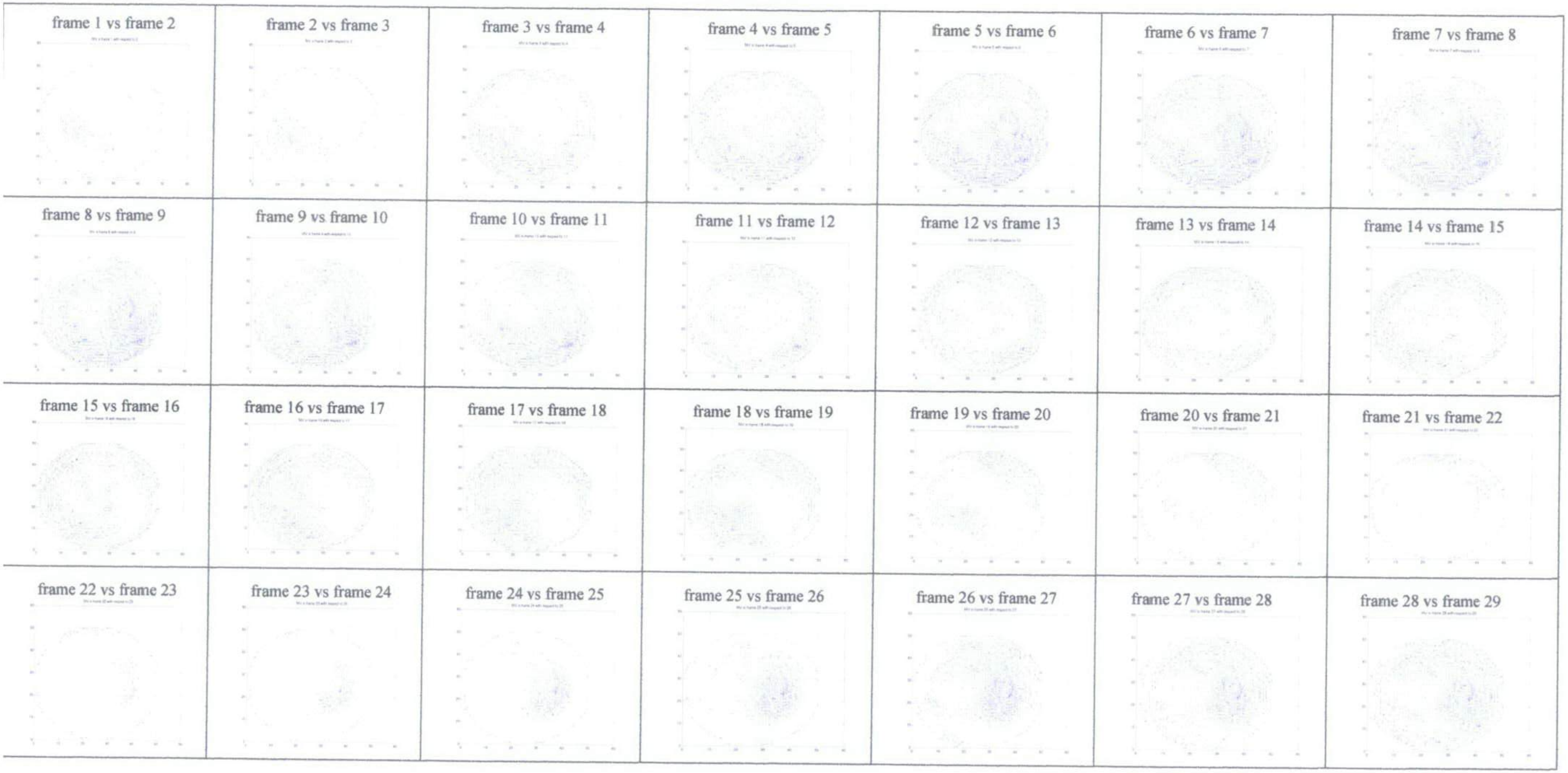

figure 72 : Activation occur in brain topographic maps for Subject 7

figure 73 : Activation occur in brain topographic maps for Subject 8

figure 74 : Activation occur in brain topographic maps for Subject 9

figure 75 : Activation occur in brain topographic maps for Subject 10